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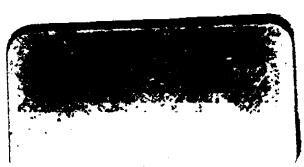

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34 SCOTLAND.

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN,

AND OF THE

MUSEUM OF PRACTICAL GEOLOGY.

THE GEOLOGY OF

EASTERN BERWICKSHIRE.

(MAP 34.)

BY

ARCHIBALD GEIKIE, F.R.S. EDIN., F.G.S.

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GEOLOGY OF EASTERN BERWICKSHIRE.

(Sheet 34, Scotland.)

CHAPTER I.

Physical Features of the District and General Distribution of the Rocks.

The present Map represents a triangular portion of Berwickshire occupying about 120 square miles. This area extends along the margin of the German Ocean from the village of Cockburnspath nearly to Berwick-upon-Tweed, and advances inland along the southern base of the triangle to the outskirts of the town of Dunse. It thus includes the eastern extremity of the Lammermuir Hills, the undulating ground between St. Abb's Head and the mouth of the Tweed, and a small part of the northern edge of the great valley or "merse" of Berwickshire.

This proximity of high uplands to a rich agricultural plain gives rise to considerable diversity in the physical features of the district. A line drawn in a north-easterly direction from Dunse Law to the sea at St. Abb's Head divides the Map into two nearly equal portions. That to the north-west is the region of the Lammermuir Hills, which plunge into the sea along the range of precipitous cliffs between the Siccar Point and Coldingham. Hence it is only the north-eastern extremity of this range of hills which comes within the limits of the present Map. The general scenery of this portion however corresponds to that of the more westerly parts of the chain. It consists of highly inclined Silurian grits and shales, but nowhere rises to a height of more than between 800 and 900 feet above the sea. Its outlines are rounded and undulating, save where fissured here and there by steep ravines. Wide heathy uplands stretch away inland, sinking gently down into tortuous intervening valleys, but with no determinate system, so that the chain is thus composed of numberless smooth-backed coalescing ridges and hills. The surface of this hilly ground is for the most part covered with heath and bent, and is used as a pasturage for sheep. The narrow sequestered valleys are dotted with solitary farmsteads where the adjacent slopes have been laid under the plough, and the fields are now creeping further up the hill sides every year; but the whole district still retains its quiet pastoral character. The portion of the Lammermuir chain embraced in this sheet is traversed by two main valleys; that of the Whiteadder Water, and that followed by the line of the North British Railway. Of the vale of the Whiteadder in its course across the hills only a small part is here represented, where the stream, bending round and piercing the granitic mass of Cockburn Law, issues from the high grounds at Preston, about two miles to the north of Dunse. The valley in which the railway runs crosses the chain completely from side to side. Its summit level, forming the watershed of the hills, in place of being a ridge dividing the sources of the streams, is a flat peaty meadow from the margin of which the ground rises rapidly on both sides. From this point the valley stretches to the south-east for about a mile, where, at nearly right angles, it receives the Eye Water,

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and then pursues its course until at the village of Ayton, this stream is turned sharply to the north-east, and cutting a deep ravine across some hilly ground reaches the sea at Eyemouth. The north-western continuation of this great transverse valley is the deep glen occupied by the Pease Burn. This stream for the first half of its course flows in a south-easterly direction until it reaches the flat peaty meadow just referred to, when, instead of continuing in the same direction and joining the Eye Water, it wheels round at an acute angle to the north, and enters the ravine which reaches the sea to the east of Cockburnspath. This marked defile ranges from 100 to 150 feet in depth, and is well known from the arch which crosses its seaward end, called the Pease Bridge. As it lay across the ancient highway along the east coast between England and Scotland, it was always a pass of importance. Cromwell wrote of it as "the strait pass at Copperspeth,* where ten men to hinder "are better than forty to make their way." Patten, a Londoner who accompanied the Duke of Somerset's expedition into Scotland in 1548, describes it as "a valley running straight eastward and toward the "sea, a xx skore broad from bank to bank above, and a v skore in the "bottom, wherein runs a little river; so steep be those banks on either "side, and deep of the bottom, that who goeth straight down shall be in "danger of tumbling; and the comer up so sure of puffing and pain; for "remedy whereof the travellers that way have used to pass it, not by "going directly, but by paths and footways leading slopewise, from the "number of which paths, they call it (somewhat nicely indeed) the "Peaths."

This remarkable ravine, however, is not the only one of the kind along the flanks of the Lammermuir Hills. Several of smaller dimensions occur in the same neighbourhood, where small rivulets have worked their way through the red sandstones and conglomerates that flank the Silurian rocks of the chain. Some deep rents are also to be seen along the coast, as at Dulaw, where the streamlet has formed a ravine fully 100 feet in depth. On the south-eastern edge of the chain the water-courses are less precipitous; instead of jagged defiles, they usually occupy the bottom of valleys that are bounded on either side by sloping hills.†

Of the ground to the north-west of the Lammermuir chain it is unnecessary to speak here, as only a corner enters the area embraced in the present sheet. It is there, however, that the ravines of the Cockburnspath district occur. The south-western edge of the chain corresponds with the line already indicated, which extending from Dunse to the sea at Coldingham, forms a well defined boundary. From the Whiteadder at Prestonhaugh to the valley of the Eye at Reston, the hills rise rapidly from the plain to a height of between 800 and 900 feet, forming a long smooth-backed ridge, known as Bunkle Edge. Between the Eye Valley, again, and the Coldingham Shore the distinction between hill and plain becomes in a manner lost, and the surface is broken up into an endless series of ridges and of interlacing depressions that rarely deserve the name of valleys.

The district which lies to the south-east of the Lammermuir Hills, and occupies the other half of the present Map, may be regarded as a part of the great merse or plain of the Tweed Valley, bounded, however, on the north-east by a band of hilly ground—a sort of spur from the Lammermuirs—which extends along the coast from Coldingham by Lamberton

* A corruption still used for Cockburnspath.

† Mr. Milne Home has described some of these ravines in his paper on the Geology of Berwickshire, Trans. Highland Soc. xi. 180.

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to within a mile of Berwick, when it sinks down into the plain. This part of the county is in truth a bay from the level plain of the merse, sweeping northward past Dunse till it reaches the foot of the hills of Bunkle Edge, whence it deflects towards the east, and, skirting the high ground of Lamberton Moor, joins the main valley again at Berwick. It is traversed by several streams descending chiefly from the hills that lie towards the north-west. Of these the most important is the Whitadder, which, as just mentioned, issues from the Lammermuir chain at Prestonhaugh, and thence runs in an easterly direction until it falls into the Tweed, nearly two miles above Berwick. Its banks exhibit in many places precipitous sections of the strata which occupy the greater part of the Berwickshire plain, and which are also laid open in a series of deep ravines opening upon the Whiteadder in the neighbourhood of the village of Foulden.

The coast-line along nearly the whole of the district pourtrayed on the present Map is rocky and precipitous. Here and there, as at Cockburnspath, Coldingham, and Eyemouth, there are sandy bays bounded by gently sloping shores or by bluffs of lesser elevation. But by much the larger portion of the sea-margin is a precipitous cliff-line, hardly accessible save by boat. At Tun Law, to the west of St. Abb's Head, it rises to a nearly vertical height of 500 feet, and forms thus the highest range of headlands on the east side of Scotland. This wild coast is worn by the incessant surge into caves and arches and solitary stacks; the haunt of multitudes of sea-fowl. The tides run swiftly round the headlands; hence, even on the calmest summer day, when the surface of the water is scarce roughened by a ripple, the white foam may yet be seen breaking over many a half-sunk skerry, and mantling along the base of the cliffs. The forms of these precipices vary with the changes of geological structure, the most lofty and rugged being these of the convoluted Silurian strata, with their associated masses of igneous rock, while the most fantastic in outline and the richest in colouring are these of the red and mottled carboniferous sandstones.

The oldest formation shown on this Map is the Lower Silurian. Its area coincides with that of the Lammermuir chain, and with that of the high ground which forms Lamberton Moor extending from near Berwick to Eyemouth. A third, and considerably smaller portion is seen on the shore for about a mile and a half between Coldingham and Eyemouth, whence it extends for rather more than two miles inland in a south-westerly direction. Next in order of age comes a remarkable series of volcanic conglomerates, ashes, red felspathic sandstones and marls, which from the scanty fossils detected in them are assigned, though with some hesitation, to the horizon of the Lower Old Red Sandstone. They rest unconformably on the Lower Silurian strata, and are seen at two localities on the coast, at Eyemouth and at Coldingham, in both of which they separate the smallest Silurian patch from the two larger ones. They then unite towards the south-west in a broad belt, which, extending across from Bunkle Edge to the foot of the Lamberton Hills, proceeds in a south-westerly direction until it is abruptly and unconformably overlaid by an irregular band of red sandstones and marls belonging to the Upper division of the Old Red Sandstone. At Prestonhaugh on the Whitadder this latter band rests directly on the Silurian grits and shales, whence as it wheels round by Dunse Law, it expands into the great range of conglomerate hills of Harden, and then into the basin of red sandstones that flank the Lammermuir chain throughout the rest of this county. To the east of Dunse this strip of Upper Old Red Sandstone after widening out between Bunkle Edge and Lamberton Moor to a breadth of two miles, rapidly dies away, and is succeeded by the Lower Carboniferous series.

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By referring to the Map it will be seen that the boundary line between the upper members of the Old Red Sandstone and the base of the Carboniferous group runs from Prestonhaugh on the Whiteadder in an E.S.E. direction, keeping parallel to the course of that stream until near Mordington the Old Red Sandstone disappears, being overlapped by the Carboniferous strata which rest directly on the Silurian. The strike of the Carboniferous beds, however, continues the same until about a mile from Berwick, when it takes an abrupt turn to N.N.W., owing to the occurrence here of a large fault. The effect of this dislocation is to throw down the Carboniferous beds against the older formations, and to extend them as a narrow belt between the high grounds at Lamberton and the shore until at Burnmouth the fault reaches the coast-line and the Carboniferous strata, tilted up on end, then run out to sea. On the north-west side of the Lammermuir Hills, another portion of the Old Red Sandstone is seen resting on the edges of the Silurian grits and slates, and graduating upward, as on the south-east side, into the white sandstones of Dunglass, which there appear to form the base of the Carboniferous series. Several minor patches of Old Red Conglomerate occur as outliers in various parts of the district. One of these forms the rounded eminence called the Bell Hill immediately to the south of St. Abb's Head, another occupies the crest of the headland at Eyemouth, known as Cromwell's Fort, a third hangs as a prominent crag on the seaward face of the Chesters Hill at Burnmouth, a fourth of only a few yards in circumference lies near the bottom of the Burnmouth ravine, a fifth is cut open by the railway at Lamberton Shields, and the sixth, and largest of all, occurs on the west side of the great fault between Marshall Meadows and the Steps of Grace. The relative proportions of these outliers are best shown on the Map. No such detached parts of Carboniferous rocks occur in the district.

The igneous rocks shown on this Map are for the most part associated with the Silurian strata, and with the ashes and sandstones of Lower Old Red Sandstone age. One large mass of greenstone, however, occurs in the Upper Old Red Sandstone, and forms a considerable hill to the west of Dunse, a capping of basalt crowns Dunse Law, while several dykes occur in the same neighbourhood. Five dykes of greenstone were observed on the coast running out to sea in an E.N.E. direction and cutting through both Carboniferous and Silurian beds. One of them even crosses the large fault, as may be seen along the face of the precipitous cliff as well as in the railway cutting to the north of Lamberton Shields.

CHAPTER II.

Lower Silurian Formation.

The district embraced in the present Map has a peculiar interest in relation to the history of geological science. It was here, among the contorted Silurian strata which form the wild headlands to the east of Cockburnspath, that Hutton demonstrated the revolutions which the earth's crust had undergone by showing that grits and shales, originally deposited horizontally on the sea bottom, had come to be convoluted and piled up on end, and that their exposed edges had been thereafter exposed anew to the action of the waves which had heaped upon them a set of gently inclined conglomerates and sandstones. Here too, amid the same contorted Silurian strata, Sir James Hall made his well-known observations on the

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effects of lateral pressure in convoluting large masses of stratified rock.* Nor could the early observers have lighted on a district that more clearly illustrates some of the fundamental principles of geology. The rocks are laid bare in long lines of natural section, both upon the coast-line and among the numerous water-courses of the interior, while later years have added the deep cuttings of the North British Railway across the Lammermuir chain.

The Silurian strata of this region, as pointed out so long ago by Hutton and his followers, are in the highest degree convoluted and broken. Yet this disturbance has not in any way destroyed the stratified appearance of the rocks, although it has rendered the task of elucidating their order of succession a difficult and perhaps even an impossible one. The strata are thrown into rapid flexures, the axes of which run in parallel lines from N.E. to S.W., or N.N.E. to S.S.W. This feature is characteristic not of this district only, but of the whole Silurian tract of the South of Scotland. So persistent is this line of strike of these vertical and highly inclined beds, that the observer may steer his way over the moors and mountains in a straight north-easterly direction by merely keeping his eye on the exposed edges of the rocks as they crop out in the water-courses and along the hill-sides. If, however, he crosses the strike at right angles, he is perplexed with the rapid and apparently inexplicable changes in the dip of the strata. For some way, perhaps, he has traced a set of grits dipping, it may be, at an angle of 70° or 80° to N.W., and he believes that the clue of the order of sequence has at length been obtained. Before long, however, he finds the beds become vertical, and suddenly take a contrary dip towards the south-east, and while he casts about for some character, lithological or otherwise, whereby the stratigraphical succession may be followed out, he is met by an abrupt return of the dip to its former north-westerly direction. Hoping now to regain the lost thread, he follows on, trying at every step to identify bands of grit or shale with those that had previously presented themselves, when again another contortion takes place, the inclination changes once more, and perchance he abandons in despair any attempt to follow out the succession of the Silurian rocks of the Lammermuirs.

Some of these perplexing and seemingly anomalous features receive their explanation in the range of sea-cliff towards the east. In the interior we walk along the denuded edges of the strata; and many intervening parts are there obscured by the drift of the valleys, or by the thick moory vegetation of the hills. But along the coast line, where the waves have cut a vertical section some two or three hundred feet high, and several miles long, the origin of the difficulties that so beset us among the uplands is at once explained. We there see that in ascending the river-courses we had been in reality crossing a series of rocks thrown into rapid arches and troughs, and that the abrupt and puzzling changes of dip really represented the alternating sides of these great folds and curvings of the strata. As the general trend of the coast line is from N.W. to S.E. it crosses the strike of the beds, and hence the section thus laid bare represents pretty nearly the true relative proportions of the curves, not much distorted, as they would be by any marked deflection from a line transverse at a right angle to the axis of plication. With a sinuous outline, there are of course numerous parts of the coast where the

* See Hutton's "Theory of the Earth," vol. i. p. 454 *et seq.*; Playfair's "Illustrations of the Huttonian Theory," p. 213; "Life of Hutton," Playfair's works, vol. iv. p. 78; Sir James Hall, "On Vertical and Convoluted Strata," Trans. Roy. Soc Edinb. vii. 79; "On the Revolutions of the Earth's Surface," Ib. p. 162.

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cliff exhibits a more or less oblique section, but the same indented character enables us to correct such distortion, by constantly presenting coves and creeks where the true direction of the beds is shown.

Yet although the coast rocks explain the causes of those rapid changes of inclination which are often so difficult to follow in the inland parts of the country, they present new obstacles to the determination of the order of succession among the Silurian strata of this part of Scotland. The curvings are not all mere simple folds, but are sometimes so reduplicated upon each other that it becomes next to impossible to decide whether, after we pass beyond such a disturbed belt, we are upon higher or lower beds. And as if to crown the difficulties, the curves are not unfrequently broken through by faults. These cut off abruptly the thread whereby the observer may have been attempting to follow out the order of superposition, and they leave the task well nigh as hopeless as ever.

The great Silurian tract of the South of Scotland appears to be traversed along its centre by an anticlinal axis which, passing south of the town of Moffat, stretches away towards the German Ocean on the one side of the island and to the Irish Sea on the other.* On the north-west side of this line the strata, notwithstanding their endless crumplings and plications, dip on the whole away towards the north-west, so that in passing over the hills on that direction, we gradually ascend from a low part of the Lower Silurian series to the upper parts of that group (as developed, for instance, in the valley of the Girvan, in Ayrshire) until we reach even the true Ludlow rocks of the Upper Silurian series, as shown among the hills of Lesmahagow and in the Pentlands. Again, in traversing the chain towards the opposite quarter we meet with the same evidence of a gradual ascending series from the dark slates at the bottom of the system up into the Upper Silurian strata of the south of Kirkcudbright and the hills of Cumberland.† This structure is rendered visible by a gradual change in the lithological character, and still more in the fossil contents of the strata, rather than by any clearly traceable upward succession of bed upon bed. We see that, viewed as a whole, the outer edges of this long Silurian zone are formed of strata higher in geological position than those of its centre. But it is very difficult to decide in any particular district whether one set of beds is actually higher or lower than another. At the best the decision in most cases rests only upon a combination of probabilities.

The anticlinal axis observable in the central and south-western portions of the Silurian belt is in all likelihood prolonged to the north-east; but I have not yet been able to recognize it with certainty in the Lammermuir district. From Dirrington Law across the Lammermuir chain to Gifford the prevailing inclination of the Silurian strata (as shown on Sheet 33 of the Geological Survey) is towards the north-west. These hills therefore probably lie on the north-western side of the axial line. If we draw a line from Dirrington Law in a N.N.E. direction to the sea, at a point between Fast Castle and Dulaw Dean, and then examine the Silurian strata to the south-east, we shall find their general dip to be south-easterly as far as the great trough of Lower Old Red sandstones and ashes to be afterwards described. We might therefore infer that the anticlinal axis runs out to sea somewhere to the east of Fast Castle. But when we pass to the eastward of the belt of Lower Old Red Sandstone, and examine the coast section from Eyemouth to Burnmouth, we find the

* See Sedgwick, Edinb. New Phil. Journ., xlix. 369, li. 250; Nicol. Quart. Journ. Geol. Soc., vi. 53; Harkness, *op. cit.*, vii. 46, xii. 238; Murchison, Ib. vii. 162; Siluria, 3d Edit., 167.

† See Sedgwick, *loc. cit.*; Murchison, Quart. Journ. Geol. Soc., vii. 139.

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Silurian beds rising again, and dipping rapidly towards the north-west. Hence the line passing by Dirrington Law to near Fast Castle may be merely a minor axis, while the great fold lies further to the south-east, near Berwick-upon-Tweed. So much of the Silurian tract is here obscured by later formations that it will probably be safest to delay the attempt to solve this question until the districts lying to the south-west have been surveyed in detail, and the Moffat axis has been extended further to the north-east.

So far as can be ascertained at present, the Silurian strata pourtrayed on the present Map, as well as those on Sheet 33, do not belong to so low a horizon as those along the anticlinal axis at Moffat. They are probably intermediate between the dark slates of that district and the fossiliferous limestones and grits of Ayrshire, thus coinciding with the second group of Professor Sedgwick.* Such general definitions are perhaps all that can be attempted in the almost complete absence of fossils. My friend, Mr. Stevenson, of Dunse, found a fragment of a graptolite in the shales of the Dye Water (Sheet 33), but it was not specifically determined. In similar strata at the Siccar Point, I was fortunate enough, in company with Professor Ramsay and Mr. Salter, to find a well-marked specimen of *graptolithus priodon*. A few additional specimens were afterwards procured by the Survey Collector, Mr. Richard Gibbs, who, along with myself, detected another band of dark shale containing *graptolites* in the Headshaw Burn, at the head of Lauderdale (Sheet 33). Near Ellemford (Sheet 33), in a group of fine shales, I found some well-preserved tracks, apparently of annelids. With these exceptions, however, the Silurian rocks of the Lammermuirs have as yet proved barren of organic remains.

Throughout the whole of the district under review the Silurian rocks present little diversity of lithological character. They are made up of varieties of grit or sandstone and shale. The grit, or greywacké, as it was formerly called, ranges in texture from a very fine-grained homogeneous rock, usually of a dull yellowish- or blueish-grey colour, to a hard coarse sandstone, or fine pebbly conglomerate.† It occurs in bands sometimes less than an inch in thickness, but sometimes several feet. These bands are frequently separated by thin shaly partings. The shale also occurs in bands of several yards in depth, as near Siccar Point, the strata however being thin and hard, and easily separable into laminæ. It is of alternations of such compact sandstone and indurated shale that the great mass of the Lammermuir Hills consists. Not only are these strata singularly destitute of fossils, but they fail also to present any well-marked and persistent lithological zones by which their order of succession might be followed. In the course of the Dye Water (Sheet 33) indeed, we meet with certain bands of grit and shale, which can be traced from stream to stream across the hills for a distance of one or two miles; but these, as they pass under the moors, are speedily lost, and when, after an interval of several miles, we again encounter a water-course, we fail to recognize them among the vertical or convoluted strata there laid open. No beds of limestone are known to exist in this part of the Silurian region; nor has any thick bed of conglomerate been detected. The strata, in short, consist of endless and rapid alternations of the same materials, so that lithological characters alone are wholly insufficient to guide us to a knowledge of the structure of the chain.

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* Edinb. Phil. Journ. for October 1851.

† Sir James Hall rejected the "uncouth term" *greywacké*, and adopted that of *killas*, a name used in Cornwall to denote a similar kind of rock (Trans. Roy. Soc., Edinb. vii. 79). His substitute never passed into general use.

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Without pretending therefore to have succeeded in determining the true order of succession of the strata in this district, as related to the other Silurian rocks of the South of Scotland, I shall describe their mode of arrangement as revealed in the coast section from Burnmouth, where they are cut off by the Lower Carboniferous group, to near the Siccar Point, where they pass under the Upper Old Red Sandstone.

By referring to the accompanying protraction of this cliff-section (Pl. I.), the reader will observe that the Silurian strata there exhibited may be regarded as lying in a great trough, and then arching out again towards the north-west. This trough corresponds to the belt of Lower Old Red Sandstone ash. On both sides of the belt the Silurian strata, though violently crumpled and contorted, may yet be seen rising from under the unconformable newer formations. Traced towards the north-west they are found to descend again in that direction, when the Upper Old Red Sandstone covers them up. South-eastward they are replaced by Lower Carboniferous strata before they show any decided tendency to fold over towards that quarter.

Beginning then at the south-east corner of the Map, the first Silurian rocks met with in Scotland are those that extend from Halidon Hill across Lamberton Moor to Eyemouth. They reach the sea a little way north of Burnmouth, and here let us begin their examination. The deep narrow glen descending through the precipitous cliffs above that fishing village has been excavated through highly-convoluted strata of grit and shale, which are here traversed by several dykes of felstone. The great bends and twistings of these rocks are well shown, especially on the north side of the ravine, where a thick felspathic dyke, forming a prominent feature, cuts across a synclinal trough of the strata, which on the west side are thrown into a vertical position. At the foot of the ravine the shore is observed to be covered with long parallel reefs of rock covered with sea-weed. They run in a N.N.E. and S.S.W. direction, and on examination prove to be vertical, or nearly vertical, beds of sandstone and shale belonging to the Lower Carboniferous series. They are faulted against the older rocks, and will be afterwards described along with the remarkable dislocation to which they owe their present position. Turning northwards along the coast-line, high cliffs rise abruptly on the left, and a tumbled chaos of fallen blocks protrudes from the base of the slope into the sea. Among these ruins, however, not a few craggy rocks exist in place,—fragments of the cliff, which still stand up where the surrounding portions have been swept away. The most striking of these isolated rocks and reefs are dykes of felstone, which, running more or less parallel with the strike of the grits and shales, have been able to resist longer the action of the weather and the waves. These features are best displayed at a picturesque part of the coast-line, beyond which it is no longer possible to advance on foot along the base of the cliff. There, some massive felspathic dykes, traversing the convoluted strata, have been worn into isolated fragments and sea-stacks—the favourite haunts of numerous gulls and awks. One, called the Breeches Rock, consists of a dyke or bed of felstone, inclined inland at a high angle; the strata have been worn away from its lower part into a narrow arch, so that the rock, seen from some points, looks like a pair of colossal and not very elegant legs. The Gull Rock stands up, red and rugged, a short distance further north, among dark highly-twisted and broken strata. The accompanying figure represents the position of these dykes, and the contorted aspect of the grits and shales. The dyke to the left hand is the Breeches Rock, its peculiar outline, however, not being well seen from this point of view; that in the centre is the dyke of which the Gull Rock has been left as an outlying fragment.

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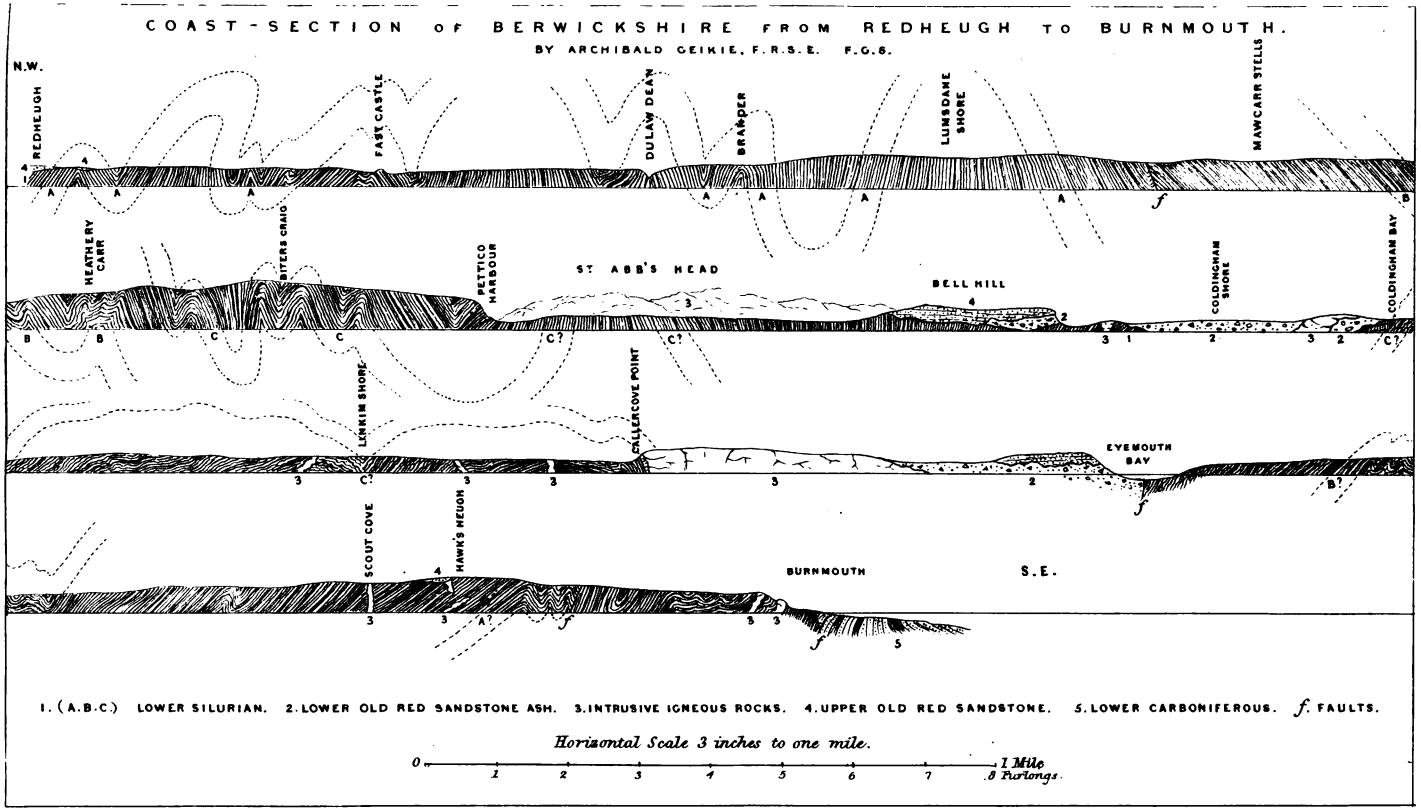

Engraved by J.W.Lowry.

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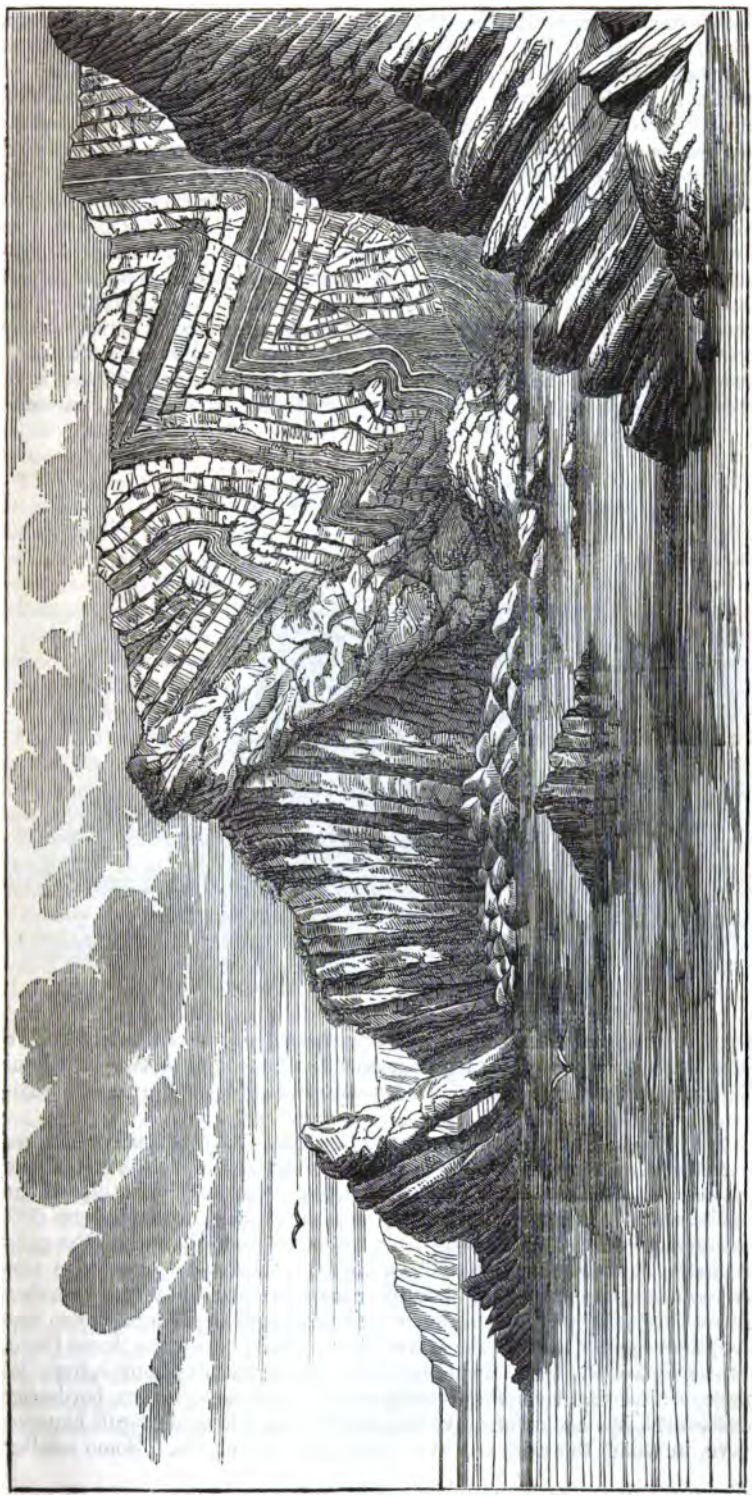

Fig. 1.—Contorted Silurian strata traversed by dykes, half a mile north of Burnmouth, Berwickshire.

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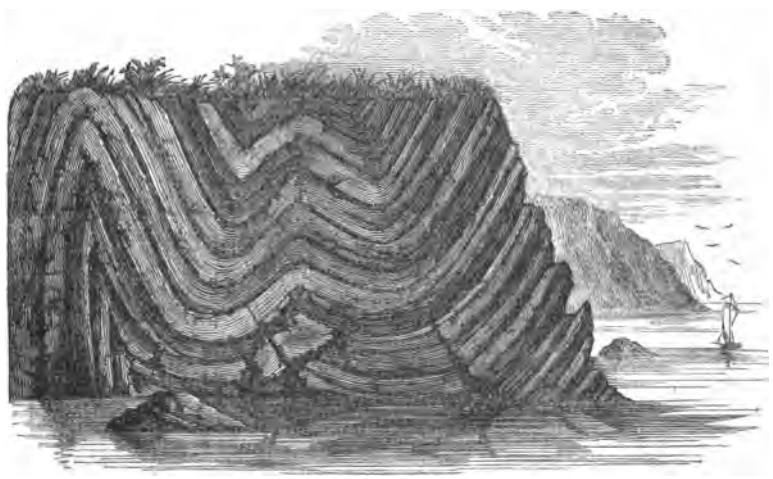
From the ravine of Burnmouth to these rocks the Silurian beds are inclined towards W.N.W. at high angles, but, as their strike is thus nearly coincident with the direction of this part of the coast-line, and as the cliff is much obscured in places by grass and debris, the details of their structure cannot be fully examined. North from the Gull Rock, however, the cliffs shoot up perpendicularly from the sea in vast walls of naked rock, along the base of which the observer can, in calm weather, make his way by boat, landing here and there in creeks and inlets to complete his observations.

Immediately west of the Gull Rock dyke, as shown in fig. 1, the strata undergo considerable plication, the arches and troughs being here and there still further complicated by small dislocations. The greater amount of irregularity may be due to the causes to which the accompanying dykes owe their origin. For as we advance northward beyond these dykes, the strata, though still violently crumpled, are bent into larger and more regular folds. The Fancove Head exhibits a well-

Fig. 2.

Curved Silurian strata at the Fancove Head.



defined trough, and from this headland westward into the little bay known as the Hurker Haven, the magnificent cliff-face contains two anticlinal and two synclinal axes, and a fault by which one side of the eastern anticline is abruptly cut off.

At the Bleak Heugh, immediately to the north of the Hurker Haven, the cliff attains a height of 337 feet above the sea, which is one of the highest points of the coast-line on the east of Scotland. The dip of the plications still continues W.N.W. at angles varying from 45° to 60°. Here and there a bed of felstone may be seen intruded among the grits and shales, as at the foot of the Bleak Heugh. Dykes of greenstone also traverse the strata, but they usually come up through nearly vertical fissures, and seldom run between the planes of bedding. The best example along this part of the coast-line is furnished by the Scout Cave. A thick dyke of dark augitic greenstone, weathering into spheroidal masses, ascends the face of the steep cliff. Its lower portion, bordering the sea-level, has been worn by the waves into a long dim gull-haunted cavern, in which the tides are ever gurgling to and fro. Some smaller

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connected veins of the same material may be seen among the strata to the south of the main dyke.

North of the Scout Cave the dip still continues north-westerly, though the strata are subjected to many minor twists and folds. These bendings increase in number as we advance towards Eyemouth, until in the space of half a mile east from that village they are so abundant that it is impossible to represent them on the Map; nay, it becomes no easy task to follow them out along the cliffs. The beds are bent into endless small anticlinal and synclinal folds; and even where they do not turn quite over, they are crumpled up and puckered as if they were so many sheets of paper. Nevertheless the general inclination is still towards the north-west, until dipping at an angle of 40°–55° the strata sink below the Bay of Eyemouth, after which they do not re-appear for fully more than a mile. The west side of this bay is occupied by masses of ash and conglomerate belonging to the Old Red Sandstone series. The junction of these rocks with the Silurian series is not visible. But, as the description of the Map proceeds, this junction line will be seen to be probably a fault. (See fig. 7.)

The ash and other felspathic rocks of Eyemouth continue along the shore as far as Callercove Point, where the Silurian grits once more occupy the beach. The junction line here is well seen, and is nearly vertical; the Silurian strata dip towards a mass of felstone, from which they are separated by an intercalated perpendicular vein or bed of conglomerate. The features of this section, however, will be more appropriately described along with the felspathic rocks. The grits and shales, in some places vertical where they come close to the felstone, speedily assume a lower angle. Dipping first towards the east-north-east as if they descended beneath the felstone, they change round to north-east, north, and north-west, until they reach the ravine which opens upon Linkim Shore. The reefs upon the beach, which is here called Hallydown Shore, permit the observer to trace the full sweep of this curve, especially when looked at from the top of the cliff. They reveal also five or more knobs of a compact pink felstone, which has been intruded among the strata probably anterior to the eruption of the Callercove felstone, from which it widely differs. One of these masses is seen intersecting the grits and shales immediately to the west of Callercove Point. Another runs out to sea beyond the curious sea-stack called Linkim-Kip. In connexion with these dykes and the adjacent larger masses of felstone, it deserves to be noticed that the Silurian strata here have a markedly red colour, and are a good deal hardened, yet they are by no means so crumpled and twisted as in the cliffs between Eyemouth and Burnmouth, affording in this respect a good illustration of the fact, to which further reference will be made in a subsequent chapter, that the most violent contortions of the strata are not seen in those places where igneous protrusions are most plentiful, but that on the contrary, where such dykes and bosses most abound, there the strata have often been least crumpled. The angle of dip from Callercove Point to Linkim Shore is for some distance as low as 24°, and except near the Callercove felstone it does not reach 50°. The detached block of rock called Linkim Kip exhibits a well-marked twist in the red grits and shaly partings of which it consists. To the west of this headland, the strata, as seen along the high cliff, have a dull red colour, which has probably been superinduced upon them; they are also much twisted and broken, and have sometimes very much the aspect of burnt brick. So far, indeed, has the process of alteration been carried, that it is extremely difficult to decide whether some parts of the cliff should not be regarded as felstone. On the beach,

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however, immediately in front of this cliff the beds are seen dipping north-west at 30°–50°. They are then immediately reversed to the south-east, and arch round again into Coldingham Bay, as they do between Callercove Point and Linkim Shore. There are thus two comparatively flat anticlinal arches of the Silurian strata visible between Eyemouth and Coldingham. But although these curves are in all likelihood formed by a repetition of the same set of beds, they present some striking differences in colour, texture, and arrangement. That to the south-east, as we have seen, is distinguished by the red tint, and gentle inclination of its grits and shales. But along the north-western curve the beds have a greenish and yellowish hue, and are more broken, gnarled, and altered than in any other part of this district. The red colour in the one case is probably connected with the metamorphic action by which the beds have been altered in texture. The paler tints of green and yellow in the other instance are not greatly different from some of the ordinary colours of the Silurian rocks of the Lammermuirs. It is at the stream which descends upon Linkim Shore that the change begins. If we ascend its ravine, we meet everywhere with proofs of intense alteration and disturbance. The strata are knocked about, twisted, comminuted, burnt and fused, or traversed with intersections of felstone in a manner truly wonderful. On the shore to the north-west of this rivulet, where the reversal of the dip occurs, the beds are first of a reddish colour, which is quickly exchanged for different tints of green. All distinction of stratification is in some places wholly lost, and we are left in doubt whether we are examining aqueous or igneous rocks. A dyke of light pink quartziferous porphyritic felstone forms here a skerry called Leader Kip, and rises from among the altered strata. This, however, was the only undoubtedly igneous intrusion which I observed between Linkim Shore and the mouth of the Milldown Burn, so that in this instance, as was remarked in that of the Hallydown Shore, the intensity of the metamorphism cannot be shown to depend upon the presence of igneous masses. From the Leader Kip onwards towards the north-west, the yellowish and greenish grits and shaly partings continue to show a high degree of alteration. They are greatly puckered up and gnarled, yet their dip is easily traceable. They are first seen veering round to the east; their inclination then continues for a furlong or two towards the north-east, after which it bends round more to the north, until at the mouth of the Milldown Burn it is once more north-west. Here the rocks are in some parts slightly calcareous. A curious block of fused Silurian fragments standing on the declivity about the middle of the little bay, and known as the "Deil's Dander," indicates (I was informed) where an attempt was once made to burn these calcareous bands for lime. The headland on the north-west side of this bay, which it separates from the Bay of Coldingham, is called Homelie Knoll. It consists of the same greenish-yellow grits and shaly bands in nearly vertical beds, but much crumpled, twisted, and altered, and traversed by two small veins of pink felstone. As we advance into Coldingham Bay, the north-westerly dip becomes more and more decided, until about the middle of the bay the Silurian rocks are replaced by a series of ashes and felstones, similar to those of Eyemouth.

The shore for about a mile, or, measured at right angles to the strike of the Silurian beds, for about half that distance, is now occupied by different igneous rocks to be described in the following chapter. Passing the little fishing village of Coldingham Shore, the first trace of Silurian rocks which we encounter are two small patches of altered grit, seen on the beach between Craig Robin and the Long Carr, amid felstones and

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ashes. Immediately to the north-west along the seaward base of Bell Hill and the precipice called Halterem's Loup, hardened grits and shale bands are found dipping in a north-westerly direction at 50°. But they are overlaid by a hill of conglomerate, and from this point onwards no Silurian strata are again seen until we have passed St. Abb's Head.

By examining the various bare knolls and water-courses, however, which intervene between Bell Hill and the sea at the west side of the great headland, we can supply in part the missing parts of the section. The grits and shales, as there exposed, are nearly vertical, inclining sometimes to the north-west, sometimes to the south-east. There appear to be at least one trough and one arch between Halterem's Loup and Pettico Harbour at the west side of St. Abb's Head. But the soil and debris on the surface only permit a partial examination of the rocks.

At Pettico Harbour the coast section of the Silurian series recommences, and continues uninterrupted until the descent of the Upper Old Red Sandstone, a direct distance of five miles. These strata resemble those between Eyemouth and Burnmouth. They consist of beds of hard grit with thin shaly partings and thicker bands of shale. They are thrown into numerous large folds, and occasionally show a little minor twisting, but they are singularly free from the puckered appearance so marked to the east of Coldingham. In the five or six miles of sea-cliff, at least seventeen or eighteen complete reversals of the dip may be traced, giving rise to as many arches and troughs ;* but if we include the minor twists (such as that at Fast Castle, engraved on the Map) which are also small anticlinal and synclinal folds, we must far more than double this number. The general disposition of these curves is shown on the section, Pl. I. And their position on the ground may be gathered from the arrows inserted on the Map.

Standing on the western verge of the precipices of St. Abb's Head, the observer sees before him one of the wildest cliff-lines on the east of Scotland. The Silurian strata are there thrown into vast folds, which in oft-changing curves jut out, headland after headland, here worn into dim twilight creeks, there standing up as tangle-covered reefs and skerries, or grey sea-stacks, round which the gull, and the awk, and the Solan goose are wheeling above ; while the surge is ever breaking into foam below. His eye can trace the stratification of the cliffs as the sun-light falls on each successive promontory, now on an arch that has been half removed by the ocean ; now on a trough that descends deep into the precipice, until these details are lost in the blue distance, as the coast-line bends away by the rocks of Fast Castle.†

This range of cliffs is most conveniently examined by boat ; but in order fully to appreciate not only the grandeur of the scene, but the geological structure of the coast-line, the observer ought also to walk along the edge of the precipices. Beginning at the little bay of Pettico Harbour, which lies on the west side of St. Abb's Head, the first fold is a synclinal trough where the grits on the one side dip at an angle of 47°

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* "I reckoned sixteen distinct bendings in the course of about six miles, each of "the largest size, and reaching from top to bottom of the cliffs, their curvature being "alternately concave and convex upwards."—Hall, Trans. Roy. Soc. Edin., vii. p. 81.

† I have attempted to give the reader an idea of the forms of these cliffs in the sketch which is prefixed to the title page of this Memoir. There is a sketch of part of the same coast by Sir Archibald Alison in Siluria, 3d edit., p. 166.

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to north-west, and on the other at 35° to south-east. Proceeding westwards, we find the south-easterly inclination continuing as far as the Biters Beach, a distance, measured across the strike of the beds, of 1,000 feet. As the angle remains nearly uniform throughout this space, there must be here a section of about 560 feet of strata. After an arch at the Thrummie Carr, the dip returns at the Biters Beach to the south-east, and remains so for about 300 feet.*

A double fold then occurs, which is well seen on the skerry called Biter's Craig. A small arch, and then a corresponding trough can here be traced within the compass of a few yards, after which the south-easterly dip is resumed, but at high angles. The inclination indeed, increases so much, that as we approach Whitestone Heugh the beds are quite vertical, and even reversed 10° beyond. It is not improbable that in this reversal of dip there may be an actual fold of the strata, for the beds again become vertical at Whitestone Heugh, and then assume once more a south-easterly dip at 60°. A pretty twist is seen on a detached rock at the Little Pits, and also on the cliff above the Muckle Pits, where the cliff sweeps up to a vertical height of 500 feet, the highest headland on the east of Scotland. The south-easterly inclination, however, continues the dominant one, until as we near the Heathery Carr the strata are thrown into a number of rapid folds. Two well-marked arches and two corresponding troughs, irrespective of minor crumplings, can be counted in the space of 100 yards. The westmost of these is a remarkably sharp syncline seen on the north-west side of the Heathery Carr. The south-east dip is again resumed until at Pikie's Stell the beds gradually become vertical. In this state they are suddenly bent over into a sharp arch, but immediately with as rapid a curve they resume the usual dip at an angle of 43°. Along the cliffs that rise from the Moorburn Beach, and around the promontory of the Maw Carr, as far as the western horn of the Shilments Beach, the dip of the beds remains south-easterly, at angles which range from 43° to 60°. The direct distance is rather more than 2,000 feet, and with the strata at an average angle of 50°, this part of the coast-line must display a section of upwards of 1,200 feet of grits and shales.

The cliff, immediately before we reach the promontory of the Shilments, shows a well-defined fracture, on the west side of which the strata are twisted up into a reversed or north-west dip. The hade of this fault appears to be easterly. It does not interfere, however, with the prevalent south-easterly inclination. This is immediately resumed, and continues past the Barleyhole Rocks, the Naked Man, and the Hollow Craig. The angle varies from 50° to 70°, but westwards it gradually increases until at the Lumsdane Shore the beds are vertical. The dip is now observed to incline towards the north-west, though still at high angles. It continues in this state for 600 yards, until about 150 yards to the south-east of the conspicuous promontory of the Brander, it reaches verticality, after which it turns once more to the south-east. In this instance again it is probable that the high inclination obscures a complete reversal of the dip forming a great trough. The south-easterly dip continues along the Brander cliffs for a short distance, until at the Brander Cove, in one of the most perfect arches of this coast-line, the beds bend abruptly over to the north-west.

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* It may be necessary to repeat that these measurements are not made along the curving outline of the cliffs, but at right angles across the strike of the beds.

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Fig. 3.
Curved Silurian Strata at Brander Cove.

This is their inclination on the bold out-jutting rock called the Brander. The angle varies here from 45° to 60°, but before we have proceeded 100 yards the strata are fairly on end. At the foot of the Dulaw they are slightly inclined towards the south-east, but between this point and the Souter, they are seen to bend over into an arch and then to rise again in a perfect syncline, after which the strata continue nearly vertical, but slightly dipping to the south-east. As we pass round the Souter and go westwards, we notice a gradual change of the inclination towards the north-west, the angle still ranging upwards from 70°. This change probably indicates another great fold, the top of which has been denuded.

On the cliffs immediately to the east of Fast Castle the north-westerly dip is suddenly reversed in a beautiful trough. The folding of the beds here shows, what is often seen elsewhere in these cliffs, that the shaly partings between the thicker bands of hard grit, are sometimes reduplicated and crumpled up into minor twists, while the grit bands have only suffered from the larger bend. The north-west side of this trough sweeps up into the cliffs above Fast Castle. The ruin itself stands on a promontory where the beds show the same south-easterly dip. Immediately to the west, however, they arch over to the north-west, and in so doing display a small synclinal furrow running along the centre of the anticline. (See sketch-section of this locality engraved on the Map). The fold by which the beds are thrown over to the north-west, thus consist of two arches, with an intervening trough.

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The north-westerly dip now continues for about 1,000 feet, the only noticeable divergence being a pretty little twist which occurs at the Nick Cove.

From the skerries called The Rooks, the coast-line turns round towards the south-west, parallel to the strike of the strata; hence the structure of the cliffs is not so clearly exposed. We can see, however, that along the upper part of the precipice the north-westerly dip continues at 60° to 70°, while along the base of the cliffs the inclination is south-easterly also at 70°. The coast here, therefore, must run nearly along a synclinal axis. It soon bends round again, however, and we are once more presented with an oblique section across the ends of the strata. At the Rammel Beach the south-easterly dip is replaced by one in the opposite direction, which lasts for about 700 feet, until we have passed the Middle Craig and the Tod's Loup, when the beds turn up with a reversed inclination, and continue dipping towards the south-east, at angles varying from 55° to 70°. Immediately below the outlier of Old Red Sandstone which overhangs the Windylaw Cove, an anticlinal axis restores the north-westerly dip at an angle of 80°, and from this point the grits and shales may be seen on the beach inclined in the same direction, at angles varying down to 65°, until at a distance of 200 yards they are overlaid by the Old Red Sandstone, which now descends to the beach.

Alternations of red and white sandstone and marl occupy the shore from Redheugh for about a mile westwards to Siccar Point. At that headland a promontory of the Silurian rocks protrudes seawards from under the overlying sheets of Old Red Sandstone. The junction of the two formations was long ago described by Hutton and Playfair. The grits and shales (here containing graptolites) on the east side of the Point are first vertical, their edges being capped along the summit of the cliff by red sandstones, which dip away to the north-east. At the northern front of the promontory this inclination brings the sandstone down to the sea-level. It is then seen ledge after ledge slipping out to sea, with here and there a knob of the older strata protruding through it. On the west side the vertical position of the Silurian beds changes into an inclination to the south-east at angles varying from 55° to 65°. Proceeding westwards we find this dip to continue with here and there a little confusion, until nearly half a mile west from the Siccar Point, the grits and shales, sometimes vertical and sometimes inclined to the north-west at 50° to 60°, are finally concealed by the red sandstones. From this point northwards, the eastern coast-line of Scotland presents no further exposure of Silurian formations till after crossing the basins of the Forth, the Tay, and the Esk, we reach the Metamorphic Silurian slates and schists of Stonehaven.

The coast-line now described presents so continuous a section of the Silurian rocks of Berwickshire, that it is hardly necessary to give any details of the interior. Indeed, the inland sections are in general so interrupted, that they afford comparatively little assistance in interpreting the structure of the country. By comparing the dips inserted on the Map with the section Pl. I., and the description which has been given of the coast-line, the reader will perceive that the range of Silurian hills represented on the present Map as cut off by the sea between Siccar Point and Burnmouth, may be regarded as composed of a vast synclinal trough, with innumerable minor anticlinal and synclinal axial lines. The middle of this great basin corresponds to the belt of (Lower Old Red Sandstone) volcanic rocks extending from St. Abb's Head and Eyemouth south-westwards in the direction of Dunse and the great Merse of Berwickshire. To the north-west of this belt the prevailing

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dip is towards the south-east for three miles and a half. In this space, after protracting the angles of dip observed along the cliffs, I find that there are probably not less than 4,000 feet of grits and shales belonging to the Lower Silurian series. The lowest parts of this series appeared to me to occur about midway between Dulaw Burnfoot and Fast Castle. From this point westward the folds are so numerous that there is probably little difference between the horizon of the strata around Fast Castle and that of those at Redheugh. Arch and trough here succeed each other so rapidly, that a group of beds have no sooner plunged below the sea-level, than a reversal of the dip brings them again to the surface.

Along the centre of the great synclinal basin, if we may at least judge from the character of the coast section, the strata are flatter than towards the sides. This was shown in the two flattened arches between Coldingham and Eyemouth. Yet it is far from unlikely that this appearance may be exceptional, and due to the disturbing forces which produced the igneous rocks of this part of the district. It is certain that the Silurian rocks here show a more metamorphosed aspect than in any other part of the Lammermuir region; and this too may be connected with the same volcanic agencies. Unfortunately, there is no means of ascertaining what may be the character of the Silurian rocks along the central trough, as it is prolonged towards the south-west, for before they have reached three miles from the sea, they are covered over by the ashes and conglomerates of the Lower Old Red Sandstone, nor do they ever again come to the surface throughout the rest of Berwickshire.

Passing to the south-eastern side of the basin as it rises from the valley of the Eye Water, and sweeps up into the bold headlands of the Bleak Heugh and the moory hills of Lamberton, we find the strata, though often much convoluted, still dipping on the whole towards the north-west. They agree in all lithological features with those to the west of St. Abb's Head. For the sake of assisting the eye to follow the effect of the curves along the coast-line on the section, Pl. I., I have continued some of the bands of strata by means of dotted lines. It must not be supposed, however, that I have satisfactorily identified the bands marked A, B, and C at all the points where these letters are marked. As there are here no distinctive features by which any particular zone may be recognized among several thousand feet of similar strata, my identifications are merely approximative, having been derived from a protraction of the observations made during successive examinations of the cliff-line.

It is somewhat remarkable, that notwithstanding the great compression which these Silurian strata have undergone, anything like defined cleavage is almost unknown. They are traversed by innumerable joints and fractures, but only in one locality have I observed them to be divisible along what may fairly be called planes of cleavage. This occurs at a bend of the Whiteadder, behind the little hamlet of Elba, about a mile to the north-east of Cockburn Law. The grits and shale bands there are fairly on end, and strike towards N.E. by E. They are penetrated by one or two dykes and bosses of a pale felspathic rock, and also by veins of carbonate of copper, which were once worked here. Between Elba and the Coppermine House in the bed of the river, a group of vertical beds is traversed by a distinct set of cleavage planes, which correspond in strike with the stratification, but cross it at an angle of 33° with the horizon, or 57° from the perpendicular of the strata. Some of the grit bands are a good deal jumbled immediately to the east, and the whole aspect of the rocks here suggests very powerful pressure, and no small degree of metamorphism. The metamorphism of the

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Silurian rocks, however, will be more properly discussed along with the felspathic rocks, which are so frequent an accompaniment of the altered character of the strata.

CHAPTER III.

Lower Old Red Sandstone.

The valley of the Eye Water, from Coveyheugh, near Reston, to where it bends abruptly north-eastward at Ayton, is occupied by a remarkable series of sandstones and fine conglomeratic strata for the most part of a highly felspathic character. The same rocks are exposed on the shore at Eyemouth and at Coldingham Shore; they are also seen in the Railway, and in various brooks and quarries to the south-west. The occurrence in them of some fragmentary plants and crustaceans appears to indicate that they belong to the Lower Old Red Sandstone. But for these fossils, however, their true stratigraphical relations would be very obscure. Their boundary lines with the Silurian rocks are especially uncertain, except along part of the north-west line of junction, where it can hardly be doubted that they rest upon these rocks with a strong unconformity. The south-eastern junction from the Ale Water to Millerton Hill appears to be a line of fault, while the places on the coast where the two series of strata approach each other are so obscured by masses of felstone that no safe deduction can be drawn from them as to the order of superposition.

By reference to the Map it will be seen that a band of Silurian rocks extends from the shore between Eyemouth and Ayton inland for about two miles and a half. This band is then overlapped by the series of felspathic sandstones now under discussion. It forms in short an axis over which these sandstones are folded. Hence if we pass to the south-west and examine the sections in the Eye Water, we find the sandstones there disposed in an anticlinal arch, those to the south-east dipping in that direction at angles of 35° to 45°, while on the opposite side of the fold the inclination is toward the N.W. at similar angles, until at Reston the strata begin to rise again and slowly dip away from the Lammermuirs. Between this axial line and the south-eastern boundary of these Lower Old Red Sandstones, the strata do not rise again with a north-westerly dip. They seem in consequence to dip under the Silurian rocks of Prenderguest and Ayton Hill, but this position is explicable by a fault running from Eyemouth by Ayton and Prenderguest, and overlapped by the Upper Old Red Sandstone of Edingtonhill.

Such is the structure of the area of Lower Old Red Sandstone where crossed by the line of the Eye Water. If however, we try to trace this arrangement towards the sea, we soon discover that as the rocks proceed towards the north-east they change their character to a remarkable degree, losing indeed for long distances all marks of stratification, and that moreover they are confused by dislocations, and by a set of intruded felspathic masses. As a rule we find them coarsest in composition, and most tumultuous in arrangement nearest the sea. From the coast inland they gradually become finer, until at Auchencraw, where they pass under the Upper Old Red Sandstone, they assume many of the features of ordinary sandstones and shales.

That these rocks are to a considerable extent the result of volcanic eruptions over the bed of the Lower Old Red Sandstone sea does not admit of doubt. It is particularly observable in such sections as those below the Fort which forms the north-western headland of Eyemouth

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Bay. There, both along the cliffs and on the beach, a light purplish-grey mottled rock—a true volcanic ash—is well exposed; even on a casual inspection it is seen to consist a mass of angular and sub-angular fragments chiefly of various felspathic and porphyritic rocks. Occasionally the eye seems to detect traces of stratification, but these are speedily lost again, and after a short interval others, disposed perhaps in a different direction, take their place. But the rock when viewed as a whole is eminently unstratified. The matrix is felspathic, of a light grey colour, often with broken crystals of felspar and imperfect tabular crystals of black mica. Of the enclosed stones not a few present a finely-laminated texture, as if they had been fragments of some well-stratified felspathic ash. The irregular manner in which the stones are imbedded in the general mass, gives it an additional air of confusion, for the well-defined layers of each stone are disposed in a different direction, and at a different angle from those of its neighbours. Tracing the rock along the cliff towards its northern extremity, we find the enclosed fragments become fewer in number, and the rock by degrees assumes very much the aspect of a porphyritic felstone, beyond and apparently below which the ash re-appears and seems to dip in a north-easterly direction. This felstone, however, is one of the most difficult rocks of the whole district accurately to determine. At some points it contains various felspathic stones, and in such cases really does not differ from the brecciated rock of Eyemouth Bay, with which it might then be classed as a true volcanic ash. But only a few yards off it loses its included fragments, assumes an unmistakeably porphyritic character, and cannot be described except as a felstone. While mapping its position during the progress of the Survey, I at one time called it an ashy felstone, regarding it as a melted rock which had received in its progress over the sea-bed an accession of stones and smaller lapilli. Again I looked upon it as more probably an ash, that had been showered out as a mass of dust and broken crystals, with fragments of various rocks. In short it seemed to change its character so often that it is only with extreme hesitation that I have ventured to colour it as a felstone. Its origin, however, is clearly distinct from that of those dark red or brown felstones which have been intruded among the Silurian and Lower Old Red Sandstone strata. That it was emptied over the sea-bottom and not thrust among rocks already formed, hardly admits of doubt.

The upper part of the cliff of Eyemouth Fort is capped by a cake of conglomerate and pebbly sandstone lying unconformably on a denuded surface of the rocks just described. This cake belongs to the Upper Old Red Sandstone series, and will be described in a subsequent chapter. Passing round the headland, with its singularly picturesque creeks and crags, we find on its north-western side, as we approach Killiedraught Bay, that, as just mentioned, the ash re-appears, rising from under the porphyritic mass with an E.N.E. dip. Both here and in Eyemouth Bay the two rocks appear to shade into each other. The ash, however, has by no means the same coarse confused arrangement by which it is marked only a quarter of a mile to the south-east. It is much finer in texture, distinctly stratified, and contains two, if not more, beds of a compact red felstone, which are well seen on the east side of Killiedraught Bay. Below them and nearer the southern angle of the Bay, the ash is finally replaced by a mass of felspathic rocks which occupy nearly half a mile of the shore, as far as Callercove Point, and form a range of cliffs 75 to 100 feet in height. Here again there is the same difficulty of ascertaining the origin of rocks that assume the characters both of lava and of ash. The transitions which occur at Eyemouth Fort are repeated; at one moment the rock would be unhesitatingly pronounced an ash,

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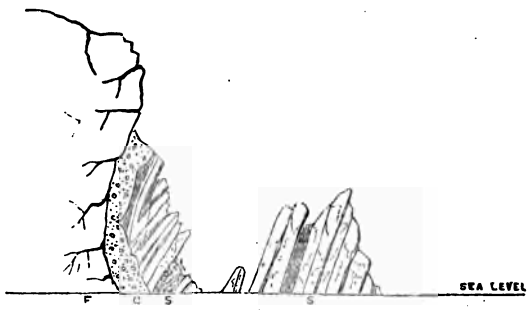
again, after an interval of only a few yards, it might be as confidently regarded as a felstone; while towards the north-west it presents not a few resemblances to altered Silurian grit. As in the case of the rock at the Eyemouth promontory, I have coloured this range of cliffs as felstone. They do consist in places of a dark red compact lava-form rock, about the origin of which doubt can hardly be entertained. The greater part of the cliff, however, is formed of a variously tinted porphyritic rock, while here and there, as in the south beach of Killiedraught Bay, there are patches of unquestionable ash.

At Callercove Point the felstone is succeeded by Silurian grits, which on the cliffs are vertical or highly inclined, but on the shore dip E.N.E. at 33°–55°. The junction, which presents some features of interest, is sketched in Fig. 4. The edge of the felstone is vertical, and even overhangs

Fig. 4.

Junction of Felstone and Silurian rocks, west side of Callercove Point.



F. Felstone. C. Conglomerate. S. S. Silurian grits and shale.

a little to the west. Between it and overlapping the ends of the Silurian beds there is an irreguliar and nearly vertical band of brecciated conglomerate. The Silurian grits become more twisted as they approach this conglomerate, and their truncated edges can be seen distinctly covered by the latter rock. There must have been considerable disturbance here at a time posterior to the production of the igneous masses. When these were erupted the conglomerate may have formed part of a gravelly deposit gathering over the sea-bed and covering the edges of the contorted Silurian strata. The felstone in this way would abruptly close the formation of the shingle by rolling over it to form that great sheet which extends along the cliff to Killiedraught Bay. But after these events the old sea-bed has been here upheaved into a vertical position, and even partially overturned, and thus the felstone and conglomerate, originally more or less horizontal on the inclined Silurian strata, are now placed on end.

From this part of the coast as far as Coldingham Bay the only rocks which occur are Silurian grits and shales violently contorted and traversed by irregular dykes and bosses of various felspathic rocks. We meet with the ash again on the north-west side of Coldingham Bay, whence it extends along the shore as far as Horsecastle Bay, with the exception of a short interval at the precipice below Bell Hill, called Halterem's Loup, where Silurian strata have been laid bare by the waves. Beginning at Coldingham Bay, we find an ash closely resembling that of Eyemouth Fort. It is in places quite as coarse and unstratified as in the latter locality, and the composition both of the matrix and of the included angular stones is equally felspathic. It is wholly impossible along this part of the coast-line to determine in what direction the ash may dip or

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at what general angle it may be inclined. For not only is the rock itself eminently unstratified, but it is traversed along nearly the whole of the shore by irregular intrusions of a dark red porphyritic felstone, which runs in and out along the beach, sometimes crossing inland, and forming precipitous banks, sometimes stopping abruptly in a tall stack before reaching high-water mark, and sometimes running out to sea in a series of rugged reefs and skerries. Those features are well shown as we approach the fishing village of Coldingham Shore. From the picturesque headland of the Castle Rock, the dark felstone runs along the steep bank on which the southern part of the village stands, until opposite the Harbour it makes an abrupt turn to the east, descends to the beach so as to allow the ashy rocks to be once more visible, and then at the mouth of the Harbour, wheels sharply round to the north-west, fringing the beach a little above low-water mark, and forming the rocky islets or *carrs* until in the little bay beyond the Black Craighead it suddenly disappears, and the ash alone occupies the shore. Along this part of the coast there is the same difficulty as at Eyemouth of determining whether certain portions of these igneous masses are to be regarded as truly melted rocks or as the result of ashy ejections. They are in places strongly porphyritic, but again after a short interval they are seen to contain large angular stones different in texture from the general matrix. After visiting the coast several times, I believe that the balance of evidence is in favour of these rocks having been produced chiefly if not entirely from showers of dust and stones. The dark red felstone, however, is undoubtedly a melted rock, but belongs, I have little doubt, to a much later period than that of the ash. It may be classed with the similar felstones which traverse many parts of the Silurian region, and to which reference will be made on a subsequent page. There is a still later igneous rock on this part of the coast, in the form of a greenstone dyke, which runs N.N.E. through the felstone of the harbour at Coldingham Shore. This dyke is probably contemporaneous with others of a similar character seen near Burnmouth, which fall to be described in Chapter VII.

The coast becomes still wilder and more precipitous as we advance northwards. The ashy rocks continue visible at intervals among the protrusions of felstone, until at Craig Robin they disappear. Beyond this great mass of felstone, in the bay of which the precipice of Halterem's Loup forms the north-west margin, Silurian strata are exposed, dipping N.N.W. under the cliff at 50°. It would appear that these beds have been exposed by the action of the sea in removing the ash which once covered them. They are only visible as far as the Loup, where they pass below the mass of felstone forming the strange castellated promontory of the White Heugh. Here too the ashy rocks re-appear, but not in the coarse unstratified form which marks their occurrence to the south-east. They are well bedded, dipping eastward at a high angle down the gully called Rutherford's Brae, where the White Heugh felstone cuts them off towards the sea. Unconformably upon their edges rests a cake of coarse reddish conglomerate, forming Bell Hill. This outlier is probably of the same age as those near Eyemouth, Burnmouth, and Lamberton—that is, fragments of the Upper Old Red Sandstone, which appears once to have covered the whole of the seaward end of the Lammermuirs and the eastern part of Berwickshire.

From White Heugh the felstone extends north-eastward in a chain of rocky islets and skerries, leaving the ashy rocks exposed on the beach and along the cliffs. Opposite the reef of the Big Black Carrs, however, it turns landward again as a broad irregular dyke, which is well seen at low water, but does not go further inland than the base of the cliff. Another mass, with minor off-shoots, forms the rugged crags of the

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Horse Castle, and thence runs westward as a line of singularly worn and caverned cliff as far as the head of Horsecastle Bay. Among these intrusive bosses of felstone, the ash is seen at many parts of the coast-line, sometimes in a hard compact form, as if its components had been partially fused together. At Horsecastle Bay there is an instructive series of sections showing the structure and composition of the ash, and the manner in which that rock is traversed by the felstones. The ash is well stratified, its beds dipping seaward at about 20°. Some layers are a kind of coarse breccia of various felspathic stones, which are often beautifully porphyritic. Indeed many parts of this brecciated ash would take a fine polish, and, if obtainable in large enough blocks, would form an excellent ornamental stone. Other beds are much finer in texture, consisting of little else than an aggregation of small angular felspathic lapilli. At Horsecastle Bay the ash finally disappears. From this point onwards, for about a mile, the coast is occupied by a huge boss of red felstone, which forms the promontory of St. Abb's Head, and descends in a series of the wildest precipices into the restless sea.

Turning inland now in a south-westerly direction, we find the same ashy deposits exhibited in some of the water-courses, as well as in several artificial openings. The first stream which assists us is the Ale Water, running in a south-easterly direction from the moors of Coldingham, and joining the Eye between Ayton and Eyemouth. A reference to the Map will show that this rivulet crosses at a right angle the band of Lower Old Red Sandstone, and also the southern edge of that tongue of Silurian grits which extends inland from the sea. Ascending the Ale, we first pass over a set of highly inclined and contorted Silurian strata. These are bounded on the west by the fault already described, along which there runs here a dyke of greenstone. From this point the water-course is occupied for more than a mile by a confused grouping of felstone bosses among the ashy rocks. The latter can be studied with advantage in the ravine called Little Dean, on the south side of the Ale, rather more than half a mile above the turnpike-road to Eyemouth, where a tiny runnel has here worked out a steep dell in a coarse felspathic conglomerate. This rock is made up of well-rounded fragments of various felstones of all sizes, up to two or three feet in diameter, imbedded in a felspathic paste. The rounded character of its pebbles distinguishes the rock here from that at Eyemouth, two miles distant, but it is still unstratified, unless some obscure lines represent planes of bedding, inclined at a high angle. In the bed of the Ale, above the Little Dean, there is a confused intermingling of felstone and ash, as on the shore. The alteration which has here been effected on the ash has sometimes almost effaced the fragmentary stones of which that rock is composed. They are in places, as it were, fused together, and it then becomes no easy matter to distinguish the ash from some of the surrounding felstones. In other parts of the water-course, particularly at the waterfall near the Linthill Tile-works, the ashy rocks seem intermingled in a perplexing manner with bands of hard grey grit, like the grits of the Silurian series. When I first ascended this stream, before having seen the coast sections, and those of the Eye Water and the Railway, the grouping of the whole series of rocks seemed at the time to be involved in utter confusion, though, before quitting the stream, I inclined to the supposition that possibly the ashy-like masses, so knocked about by dykes and bosses of felstone, might form part of the Silurian series. Nor indeed until the whole district had been examined was I able to satisfy myself that the beds in question belonged to a later formation.

From Alemill Bridge up to Whitfield the bed of the Ale Water is occupied by Silurian grits and shales, occasionally highly altered and

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penetrated by felspathic intrusions. One outlying patch of the ashy conglomerate occurs immediately below Alemill Bridge. A fault appears to separate these rocks from the continuation of the ashy deposits that run inland from Coldingham, and here cross the course of the Ale. This ashy series of rocks is well exposed in the channel of the stream for half a mile, reaching nearly as far as Alewater Bridge. Instead of a confused mass of coarse brecciform ash, however, we meet with a set of well-bedded felspathic grits and red sandstones, usually more or less ashy in composition and texture. That these strata are really a prolongation of the rocks at Coldingham Shore cannot be doubted, and they thus illustrate a feature, already alluded to, that the ash becomes finer in grain and more mixed up with ordinary sediment, as we trace it towards the south-west. Hence it seems reasonable to infer that the focus of eruption lay somewhere towards the north-east. Where these strata are first seen, after passing over the Silurian rocks in the Ale Water, they dip nearly due east at 45°. Three hundred yards higher up the stream they are inclined to the south-west, at an angle of from 15° to 20°. In some places they consist of true red sandstones, soft and crumbling, and with well-marked stratification. This character is peculiarly well shown at the point where the south-westerly dip is first observed. But the general aspect of these strata is usually such as to indicate a derivation from volcanic material. The abundance of small angular variously tinted fragments, which along with their matrix are eminently felspathic, points to the former proximity of some vent, from which dust and lapilli were thrown over the adjacent sea-bed. No fossils were detected here, though some of the beds seem far from unlikely places in which to find them.

Continuing again in a south-westerly direction, that is, further away from the old volcanic orifice, we notice the ashy strata becoming still finer in texture. They may be seen here and there on the ridge that separates the Ale from the valley of the Eye, but the best section is that exposed in the course of the latter stream, extending over a distance of four or five miles from Coveyheugh to near Ayton. The anticlinal fold, above alluded to, can be readily seen in this section; its centre being at East Reston Mill. From this point, in a south-easterly direction, the strata dip down the stream, at least as far as Aytonlaw, at angles varying from 35° to as much as 57°. Between Aytonlaw and the Silurian tract, to the south-east, they flatten out, but not for a sufficient distance to allow all the strata to come again to the surface. I have hence inferred that a considerable part of the series is cut off by a fault which, running south-south-west from Eyemouth, separates these deposits from the underlying Silurian rocks. Above East Reston Mill the section is much less consecutive, owing to the low banks and the depth of drift and soil. Where the strata can be seen, however, they dip in a W.S.W. direction as far up as Reston Mill, where they begin to undulate towards the E.N.E. Beyond this latter point the stream affords no further information, and the section has therefore to be supplied from the railway cuttings, which lie immediately to the south. There we find the ashy beds dipping gently in a south-easterly direction away from the Silurian hills on which they repose. But the actual line of junction is obscured by masses of felstone, which here, as on the shore, have invaded both the Lower Old Red Sandstone and the Silurian series. With the exception, however, of such interruptions, the two lines of section shown in the Eye Water and the railway dove-tail into each other, and afford us as complete a table of the Lower Old Red Sandstone of this district as can be hoped for.

Beginning at the base of the series, or at least at the beds which appear immediately to overlie the Silurian grits, we find in the railway

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cutting west of Reston a series of sandstones and conglomerates of a dull red colour, and strongly felspathic. Occasional partings of red marl also occur, and the whole series undulates gently towards the east or south-east. The conglomerate bands are made up of an aggregate of rounded felstone fragments in a felspathic paste. But the igneous intrusions just referred to, along with some accompanying faulting and fractures, interfere with the continuity of the series. From this point onwards, in an easterly direction, we slowly pass over an ascending section as far as the little hamlet of Braehead. Here the railway ceases to afford any indication of the underlying rock, and the channel of the Eye Water is equally obscured. It is not until after the interval of a mile that we meet with strata in place by the side of the Eye, where the stream has cut a shelving bank between Heugh-head Smithy and Reston Mill. There some bands of sandstone occur dipping in a north-easterly direction at an angle of about 12°. They are partly soft, red, and pebbly, partly of a grey micaceous texture, and in one place they contain an exceedingly hard, almost jaspideous band. What is chiefly of interest, however, in these beds is their well-stratified and fine-grained character, so different from that of the ashy rocks on the shore, and bearing out, as it does, the remark already made, that the strata become coarser and more confused in their arrangement as they pass towards the north-east.

From Heugh-head Smithy, eastwards, it would appear that the rocks rise again to the surface in a synclinal trough, so that in advancing down the stream we traverse a descending section until we reach East Reston Mill, which has been described as the central point of an anticlinal axis. Proceeding along the east side of the arch, we obtain a much more continuous section than that to the west. First, a little above East Reston Mill, some green and pinkish coloured grits occur on the side of the stream. They are, in some of their bands, very ashy in composition, and contain occasional green shaly beds, in which I detected a few imperfect plants. A dyke of dark red greenstone traverses them, seen both on the bank and in the bed of the stream. East from the mill, ashy sandstone crops out along the margin of the water-course, dipping E.S.E. at 37°. Some of the bands are, in truth, merely well-stratified ash, containing no admixture of ordinary sedimentary matter; others do not differ from the common red sandstones of the district. Similar strata, with a like south-easterly inclination and high angle, occur at intervals along the course of the Eye towards Ayton. They are well exposed in the line of rocky bank in which the Harry Craig Quarry has been opened. Beds of hard compact felspathic ash, full of angular variously-coloured lapilli, alternate with bands of firm red sandstone and marl of the usual character. For the most part the ash is greatly in excess, but there are places where the sandstone and marl occupy a half, if not more, of the general mass. The alterations are so rapid, however, that it is quite impossible, even on maps of so large a scale as six inches to the mile, to separate the ash from the sandstone. From Harry Craig Quarry the strata are visible occasionally down the course of the stream, and also along the parallel section in the railway. They are here not quite so ashy-like in appearance, but resemble ordinary red sandstones and fine conglomerates, though still with a considerable admixture of felspathic matter. Their dip in the Eye Water, at the ford below Aytonlaw Cottages, is towards N.N.E. at 20° or 22°; in the railway it is east and east by south at the same angle. It will be seen that from the perturbed area above Reston, onwards in a south-easterly direction, the strata now under description are remarkably free from those felspathic intrusions which tend so much to obscure the structure of the districts in which they occur. One small boss of felstone occurs among the conglomerates at the ford

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just mentioned, and others of similar insignificance may have escaped notice. No sooner, however, do we pass across the line of dislocation which here probably bounds the eastern margin of the Lower Old Red Sandstone series, than we find ourselves among a set of highly contorted and broken Silurian grits, with many protrusions of felstone.

Taking now another traverse still further to the S.W., we encounter the same increase of ordinary fine sedimentary matter in the strata as they recede from the coast. The conglomerates and sandstones of Coveyheugh, in the Eye Water and railway, are prolonged on the flanks of the Silurian hills, in a narrow tongue, the southern edge of which is overlapped uncomformably by the Upper Old Red Sandstones. This part of the district, however, is considerably obscured, partly by drift lying thick along the lee of the hills, and partly by a number of intrusions of felstone, which is often for some distance the only rock visible. If, passing from this conglomeratic zone, we skirt the margin of the Upper Old Red Sandstone tract, we shall find that in the bed of the rivulet due east of Auchencraw Mains, some of the finer portions of the Lower Old Red Sandstone ashy series are exposed, dipping S.E. at from 45° to 50°. They consist in the under beds of hard grey felspathic grits, interbanded with green shales, which I found to be full of vegetable remains, and where, also, in company with Mr. Gibbs, the Survey fossil-collector, I obtained a fragment of the large crustacean, known as *pterygotus*. Some of these strata are still very ashy in appearance, but the lapilli are small, and the matrix contains a good deal of sand and clay mingled with the felspathic matter. The highest beds seen here consist of fissile grey sandstones and red sandy grits with bands of marl, the whole being still more or less felspathic. The unconformity of the Upper Old Red Sandstones and marls upon these older ashy deposits is well shown at this locality. The strata just described in Auchencraw Burn dip at a high angle towards the south-east, but no sooner do we pass into the area of the upper sandstones than we find the dip change round to south and even S.S.W., while the angle lessens to such a degree that in many places the beds may be regarded as almost horizontal. This change was seen in the railway cutting at Auchencraw Mains, where some soft sandstones and marls of a brick-red colour, like those of the upper series, were exposed in a nearly horizontal position. Only a few yards towards the north-east, however, the hard ashy sandstones and shales may be seen in the brook dipping with a high inclination and at right angles to the beds in the railway, from which also they differ altogether in lithological characters. From Auchencraw eastward, across the low watershed of this part of the district, stretches an alluvial peat-covered valley, known as Billy Mire. Two small rivulets drain it in opposite directions, one flowing westward and joining the Whiteadder at Chirnside Mill, the other finding its way towards the east, until it falls into the Eye Water near Ayton. This tract affords, of course, no insight into the nature of the underlying rocks, nor until we cross to its eastern margin and reach the foot of Millerton Hill do we again catch a glimpse of the ashy series. This hill consists entirely of a fine felspathic ash, with bands of red sandstone, marl and felspathic conglomerate. These strata may be seen in fragments over its whole extent, but are best exposed in a line of low bank that runs south from the railway on the west side of the hill. Their dip varies a few degrees north and south of east, at angles of from 17° to 25°. I did not succeed in detecting any fossils in them, but it appeared a not unpromising locality for such a search. On the summit of the hill fragments of the underlying rock are especially abundant. They may be traced all down the east side, nearly as far as the line of the turnpike-road, to the east of which Silurian fragments begin to appear. The line of demarca-

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tion between the two formations, in all likelihood a line of fault, must therefore nearly correspond with that part of the high road which runs in a north-easterly direction between Millerton Hill and Whiterig.

No further trace of the felspathic strata is seen towards the south-west, as they are immediately overlaid by the Upper Old Red Sandstones of Billy and Edington Hill. Putting together the points in their structure and disposition which have been enumerated in this chapter, we find that a group of rocks occurs in this county presenting throughout the whole of its extent indications of a volcanic origin; that towards the north-east these rocks become coarse and unstratified, passing into true volcanic ash and conglomerate, and having beds of felstone associated with them; that in a south-westerly direction they lose this tumultuous unassorted appearance, become intermingled with ordinary sedimentary deposits, and contain here and there fragments of plants and crustaceans. We see, moreover, that they rest on the edges of the Silurian rocks, and are covered unconformably by the Upper Old Red Sandstone, and that they must, therefore, be intermediate in age between these two series; a conclusion confirmed by the character of the crustacean remains which indicate the horizon of the Lower Old Red Sandstone. As this part of the formation has not hitherto been recognized in Scotland to the south of the Silurian hills, some interesting questions are opened up as to whether certain districts of the South of Scotland may not belong to the same group. The occurrence of true volcanic rocks of that age is also a fact of special importance, for it may eventually help in the elucidation of the age of the Cheviot and other hills, which are certainly older than the Upper Old Red Sandstone. But these are subjects for future investigation.

CHAPTER IV.

Intrusive Rocks in Lower Silurian and Lower Old Red Sandstone Series.

In the preceding pages reference has frequently been made to certain dykes and irregular masses of various kinds of felspathic rocks, by which both the Silurian and the Lower Old Red Sandstone tracts are invaded. These rocks, occurring so abundantly in many parts of the district, present some features which could not well be described under the previous formations, and which may therefore fitly form the subject of a separate chapter.

To begin with those of the Silurian series. A glance at the Map will show the relative size and disposition of the larger felstone intrusions; but it is impossible, on so small a scale, accurately to define the numerous points and veins of felstone whereby the grits and shales are occasionally intersected as in a kind of coarse network. Some idea of the great number of these minor protrusions may be obtained by an examination of the railway sections from Burnmouth towards Lamberton, and also by a walk along the shore north from Burnmouth in the direction of the Gull Rock already described. One of the first facts which strikes the observer in the course of his explorations among these rocks is their sporadic arrangement. He seldom encounters a solitary dyke or mass. When he meets with one dyke in a stream, he almost invariably finds it but the prelude to a group of greater or less extent. Thus there is the cluster of veins and bosses round Burnmouth, another to the south-east of Eyemouth, a third in the Ale Water south of Coldingham, a fourth towards St. Abb's Head, a fifth round Cock-

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burn Law, and so on. The same arrangement occurs throughout the Lammermuirs, as shown on Sheet No. 33 of the Geological Survey. Between the groups a considerable interval sometimes occurs without any trace of felstone. Thus the triangular district occupying the north-west half of the present Map between Cockburnspath, Cockburn Law, and St. Abb's Head, appears singularly free from felspathic rocks. The small Silurian tract between Coldingham and Eyemouth is comparatively free from them along the shore, but contains a considerable number a short way inland. Again, in the area of Silurian strata stretching from Eyemouth to near Berwick, felstone protrusions abound in several places, and occur more or less in the whole.

Cockburn Law and Stoneshiel Hill form parts of one felspathic mass, separated by a deep ravine in which the Whiteadder flows.* The former eminence lies in Sheet 33, but Stoneshiel Hill, along with the valley of the Whiteadder, is displayed on the present Map. These hills are formed of one of those remarkable granitoid rocks which occur in many parts of the Silurian tract of the South of Scotland. It is in places a true fine-grained granite, composed of small crystals of quartz, felspar, and mica. The last mineral is occasionally replaced by hornblende, forming a syenite. Again, both the mica and hornblende disappear, and the rock becomes a quartziferous porphyry, and then, on the cessation of the quartz, we have a felstone of the ordinary type. Such interchanges are rapid, and may be traced in succession on the same hill-side. Thus the Whiteadder at the farm of Cockburn flows over a crystalline granite. If, however, we ascend Stoneshiel Hill in an easterly direction, we find first the mica and hornblende disappear, then the quartz, until at the east end of the hill we meet with a felspathic rock like the ordinary felstones of the district. The same change is still better seen by proceeding westward along the higher parts of Cockburn Law. If, on the other hand, instead of ascending the hills on either side, we continue up the channel of the river, the granite will be found to become finer in grain, and to show an increasing resemblance to some of the more altered Silurian grits, until, at last, the true Silurian grits are reached. This apparent gradation of these so-called igneous rocks into ordinary sedimentary strata will be immediately alluded to.

Round the outskirts of this great granitic mass a number of minor veins and irregular dykes occur. Below Cockburn Farm two such veins may be seen among the highly-altered grits and shales; one consisting of felspar and quartz with specks of brown mica; the other, an ordinary pinkish porphyritic felstone. A small knob of granite occurs between the farm-house and the Law, and a still more insignificant felspathic vein intersects the grits in the quarry to the south. Again, to the north of the main mass, many smaller protrusions may be seen in the bed of the Whiteadder and its tributaries. For instance, at the abrupt bend of the stream, before it reaches the "Devil's Dungeon," two parallel bands of felstone may be seen conforming to the dip and strike of the strata among which they have been introduced. The angle of inclination of the whole series is from 45° to 55° towards W.N.W. The upper felstone is a compact, hornstone-like rock, of a pinkish colour, save where an abundance of serpentine communicates a greenish hue. Along the junction of its upper surface with the overlying Silurian beds, the two rocks are, as it were, fused together, the grits containing crystals of

* See an excellent description of the locality by my esteemed friend, Mr. Stevenson, Dunse, in the 16th vol. of the Transactions of the Royal Society of Edinburgh, p. 33.

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hornblende and iron pyrites. At the under part of the vein the shales have been converted into a kind of Lydian stone. The second felstone dips at an angle of 52°; it is dull, granular, and porphyritic, and resembles the first in colour and in the amount of alteration which the strata in its neighbourhood have undergone. Still further northward, some interesting sections of the relation of the felspathic veins to the Silurian strata are laid bare at the old copper mines. The grits and shales are there vertical, and in some parts considerably squeezed and broken, and several veins and knobs of pinkish felstone traverse them in a direction more or less parallel with their strike. Of these there is one which stands up in a small crag in the channel of the Whiteadder, immediately below the end of the garden of the Coppermine House. It is a dull grey serpentinous rock, with small granules of transparent quartz and carbonate of lime. The cleavage of the strata here has been already referred to.

In the line of section laid open by the Ale Water through Silurian rocks between Whitfield and Alemill Bridge, several points of interest occur. Below Whitfield there are some intrusions of dull earthy felstone, occasionally of a yellow colour, like the grit among which they lie. Further down the stream, by the side of Whitfield Plantation, there are at least two patches of felstone, hard, compact, and almost flinty, graduating insensibly into the neighbouring grits and shales, which are, of course, greatly altered. Below Alemill Bridge a similar hard flinty felstone occurs, which it is difficult to distinguish from some of the more metamorphosed grits, except that it shows no trace of bedding.

The dykes of felstone which traverse the Silurian strata along the shore between Fancove Head and Burnmouth nearly coincide with the general strike, though they continue in an uneven wriggling course, and sometimes even send out minor veins that cross the strata at right angles to the strike. The coincidence of direction, however, between the dykes and the stratified rocks is never such as to leave the observer in any doubt as to the really intrusive and subsequent origin of the former. They cannot be mistaken for contemporaneous lava-flows erupted during the deposition of the Silurian series.

Along the railway cuttings at Burnmouth occur the best sections in the whole district for the display of dykes and contorted strata. From the beginning of the cuttings near Fairneyside to a point a little beyond Greystonelees, which is a space of exactly a mile, I counted 23 separate veins and dykes of various felstones intersecting the contorted grits and shales. Over the greater part of this space the rocks cannot be traced to the sea owing to the large fault which here runs parallel to the coast-line, and brings down a low zone of the carboniferous series, but in the glen of Burnmouth the felstones may be seen descending from the railway, crossing the ravine, and then running along the cliff above the fishing hamlet of Partanhall. It will be seen that here too the strike of these veins coincides on the whole with that of the strata which they traverse, though when examined in detail they are found to break through the grits and shales in the most irregular way. Nothing can well be more broken and confused than the grouping of these strata along the line of the railway. Their dip is chiefly to N.W., at various angles, from not more than 10° or 20° up to verticality; but this inclination is often reversed, and the beds are thrown into a series of rapid plications. These changes are increased by the numerous veins and dykes of felstone, along the side of which the dip is sometimes suddenly altered. The subjoined figure represents a portion of the grits and shales squeezed up between two dykes of porphyritic felstone in the railway cutting immediately to the east of the Burnmouth Station.

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Fig. 5.

Contorted Silurian strata between two Dykes of Felstone. Railway Cutting, Burnmouth.

In lithological character these felstones do not differ from those already described. They are sometimes compact, fine-grained, of a pale pink or yellowish colour, with occasional granules of transparent quartz, crystals of felspar being in such cases not unfrequent. In other places they are of a dark reddish-brown colour, more or less earthy in texture, and highly porphyritic, or they assume a firm granular or finely crystalline texture, and a light grey hue, and then they present a close resemblance to some of the more altered bands of grit. The amount of metamorphism traceable in the strata here is not on the whole great. Some of the shale bands occasionally assume somewhat the aspect of Lydian stone, but they are smashed and crumpled rather than actually metamorphosed.

The felstone of Lamberton Moor occupies a considerable area, and is one of the most beautiful rocks of the district, being highly porphyritic, and of a pale flesh colour. Its relations to the surrounding strata, however, are considerably obscured by the thick coating of heath and gorse with which these high grounds are covered. So far as it can be examined, it does not appear to call for any special remark.

Such are the chief felspathic dykes and masses that occur in the Silurian tracts of the present Map. Besides these, however, there are also some which intersect both the Silurian and Lower Old Red Sandstone strata, while others are confined to the latter series.

St. Abb's Head consists of a huge boss of felstone, rising to a height of 309 feet above the sea, which has worn it into ragged precipitous cliffs, full of clefts and caves, and fringed with sunken reefs and skerries and craggy stacks. This felstone is a compact, dull, porphyritic rock, usually of a reddish, sometimes of a blue, colour. It is separated from the adjoining Silurian rocks by a remarkable valley running in a N.W. and S.E. direction from the sea on the one side of the headland to the sea on the other. The highest part of this valley lies at its north-west end, where a mass of clay and shingle rises steeply from the beach to a height of about 75 feet. From this point the slope is gentle towards the cove called Burnmouth Harbour on the south-eastern shore. The sides of the valley are tolerably steep in places, hence St. Abb's Head stands completely detached from the adjoining high grounds, and thus that the sea once occupied the valley, and that the headland was in consequence an island, is a fact which obtrudes itself at once on the attention. When the geological structure of the locality is more closely examined, it is found that the line of the valley runs at nearly right angles to the strike of the Silurian rocks, and that the felstone therefore cuts across the truncated ends of the strata instead of lying more or less in accordance with their direction. This order of arrangement is well seen in the walk from Pettico Wick on the west side of the Head to Horsecastle Bay on the south-east side. Along the northern margin of the valley we see the line of the felstone sharply defined, while on its southern slopes the grits and shales, either vertical or highly inclined, present their edges to view, striking in a north-easterly direction at right angles with the boundary line of the felstone. These strata, though a good deal broken, are not

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much metamorphosed. As we trace the felstone in a south-easterly direction, we find that it not only cuts across the Silurian series, but penetrates also into the ashy beds of the Lower Old Red Sandstone, as may be seen in the range of rugged precipices that form the west side of Horsecastle Bay. There, however, its boundary is not a straight line. On the contrary, it sends out into the ash projecting masses, which become inseparably intermingled with the series of felstone bosses, and irregular dykes, to which allusion has been already made. Hence the rock of St. Abb's Head is certainly of later date than that portion of the Old Red Sandstone series, represented by the ashy strata of Horsecastle Bay.

From St. Abb's Head to Coldingham Bay the coast has an irregular fringe of felstone, which, as explained in the last chapter, runs in and out, as it were, among the ashy rocks. To what extent either a part or the whole of this felstone is to be viewed as, in a general way, of the same age as the ash, I have no means of determining. That it must, in the strictest sense, be later than the ash which it penetrates is of course sufficiently obvious. But it may nevertheless belong to a part of the same great series of volcanic eruptions to which that ash owes its origin. Like the rock of St. Abb's Head, it differs, at least in most places, from the ordinary character of the felstones in the Silurian tracts. It never shows that compact horny texture and pale yellow or flesh colour, with granules of quartz, so common among the dykes in the older formation, while it frequently approaches so closely to the character of an ash that its real origin becomes then liable to not a little doubt. On the other hand, it is quite true that portions of some of these masses are undistinguishable from felstones in the Silurian series. In the meantime, we are destitute of any means of deciding whether or not the felspathic bosses and veins that cut the ashy strata were produced during some part of the volcanic era to which these strata belong. All that can at present be affirmed is, that they are assuredly older than the Upper Old Red Sandstone of this district, as shown at Bell Hill and Eyemouth, that they are not earlier than the ash, and that they must accordingly belong to some intermediate stage of the great formation of the Scottish Old Red Sandstone. The same remarks hold true of that series of felstones already described as traversing the ash to the west of Eyemouth, and also to that group which occurs in the ash of the Ale Water. That some of the Eyemouth felstones are really coeval with the ash has been indicated above, but others, specially those immediately to the east of Callercove Point, are liable to the same doubt as in the case of the series between St. Abb's Head and Coldingham.

I have described together the felstones of the Silurian and of the Lower Old Red Sandstone series from the impossibility of rigorously separating them into chronological order. No one, however, can have examined them over a wide area without becoming convinced that the crystalline porphyritic masses of the Silurian tracts are of older date than the dull red lava-like bosses of the Lower Old Red Sandstone, and that, in fact, to a considerable degree, they owe their origin respectively to different sources. With regard to the Silurian masses, several points of interest have been observed in the course of this Survey.

In the first place, as noticed above, the dykes and veins have a markedly localized distribution; and this holds true of the whole region of Lammermuir.

In the second place, they appear to be most numerous where the strata are most broken and crumpled. If we examine the coast-line west of St. Abb's Head, where the Silurian beds are thrown into endless undulations without being so much fractured and irregularly squeezed as in

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other parts of the district, we find intrusive points of felstone to be of but rare occurrence. If, on the other hand, we trace the cuttings of the North British Railway near Burnmouth, or the cliff sections to the north of that village, we see a vast number of veins and tortuous dykes traversing a series of greatly disturbed strata. Such an association of so-called igneous masses with dislocated strata is commonly regarded as an example of cause and effect, the dykes having been ejected in a molten state from below so as to disrupt, crumple, and metamorphose the rocks through which they passed. It would seem, however, to be nearer the truth to assume the rents of the strata to be the cause of the appearance of the dykes.

In the third place, the Silurian strata have not undergone the greatest amount of alteration where the dykes and veins are most numerous. This may be readily ascertained by comparing, say, the Burnmouth sections, where the felstones are so abundant, with those of the coast at Coldingham Bay, where felstones are rare, but where the grits and shales have been intensely altered.

In the fourth place, there is a correspondence between an increased crystalline texture of the felspathic masses, and a higher metamorphism of the strata; in other words, where these masses are most crystalline and granitic, there the metamorphism is greatest. It is only where there is a large area of felspathic rock that we meet with a granitic texture. If there be but dykes and small bosses, we may find some of them made of a crystalline porphyry, but this porphyry does not shade into a true granite. As an illustration of this feature it is enough to point to the case of Cockburn Law and Stonesheil Hill. The granite of Priestlaw (Sheet 33) is another, and perhaps still better example. A central area of crystalline granite is found to pass into porphyry, which shades almost insensibly into the surrounding grits and shales. In some of the river-courses, as for instance in that of the Fassney Water, it is sometimes hardly possible to decide where the stratified rock ends and the unstratified rock begins. Similar gradations of grit and shale into a felstone occur in the Ale Water.

From these facts the inference seems a just one, that the felspathic masses of the district have not been the actual cause of the metamorphism of the Silurian strata. I believe we must seek for a less obvious, but more potent agency, and regard the felstones, granites, and metamorphosed grits as being but various stages in the same process of change. Into the nature of that process it would be out of place in this memoir to inquire. I merely may remark in concluding this part of the subject, that the metamorphism appears to have been developed, not equally throughout the district, but in points of greater or less extent, that it is most intense where it can be traced into granite as into its ultimate stage, and that it is not dependent upon an abundance of dislocations and intrusive dykes. It was perhaps closely connected with the effects of great vertical and lateral pressure, whereby the strata were compressed without actual fracture. Wherever, owing to a failure of this pressure in one direction, the beds have been much broken, dykes of felstone have ascended through the rents, but the extent of the metamorphism is not thereby increased, if it be not in some cases really lessened.

Nothing certain can be said as to the geological age of this metamorphism, except that it must be older than the Upper Old Red Sandstone of the district, since the conglomerates of that formation contain in abundance fragments of the altered strata, with their felstones and granites. It may, perhaps, be older than even the Lower Old Red Sandstone of Berwickshire. That all the felstones of the Silurian tracts belong to the metamorphic series is not asserted. It may be that some

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of them, more especially the dull red lava-like varieties, should be classed with those in the Lower Old Red Sandstone, which they closely resemble. As to the age of the latter series, I can only repeat a previous remark, that as the Upper Old Red Sandstone of the district covers them unconformably, they must belong to some intermediate part of that formation.

In certain localities the Silurian and Old Red Sandstone series are cut through by dykes of greenstone. These, however, belong to a much later period than those described in this chapter, and they will accordingly be noticed on a subsequent page.

CHAPTER V.

Upper Old Red Sandstone and Conglomerate.

If the reader will consult a geological map of Scotland, he will find that the Upper Old Red Sandstone of the present sheet of the Geological Survey is merely a narrow eastward prolongation of the broad belt of that formation which extends from Dunbar across the Lammermuir Hills to the flanks of the Cheviots. There are two portions delineated here, one on the north side of the Silurian chain at Cockburnspath, the other on the southern flank of the hills running eastward from near Cockburn Law to Mordington Church. As the former area is of very limited extent, and belongs more appropriately to Sheet 33, it will be described in the Memoir to accompany that Map. Nothing, therefore, need be said of it further than that it is admirably exposed along the cliffs of the Siccar Point, where its junction with the highly inclined Silurian rocks was first described by Hutton, and afterwards by his biographer Playfair.*

The band of red sandstone which stretches across from the Lammermuirs to the Lamberton Hills rests at either end on steeply inclined Silurian strata, while over the intermediate space it lies unconformably on the ashy bed of the Lower Old Red Sandstone. It is covered by, and graduates upward into the sandstones and shales of the Lower Carboniferous series, which, by trending towards the Silurian rocks of the Lamberton Hills cuts off the eastward extension of the red sandstone. Measured across the broadest part, this band does not probably contain a thickness of more than 1,000 feet of strata. Hence it can be regarded as representing only a portion of the Upper Old Red Sandstone of the South of Scotland. It contains the highest beds of the formation, as these begin to shade into the Carboniferous series. That it lies on the same general horizon with the other red sandstones and conglomerates of Berwickshire, may be inferred from the continuity of the beds, and also from similarity of fossil contents. Various ganoid scales and plates † have been found in the red pebbly sandstones of Prestonhaugh and Cockburn Mill on the Whiteadder, and also in Harelaw Quarry near Chirnside. Portions of the *Cyclopteris Hibernicus* have also been

* "Theory of the Earth," vol. i. p. 454; Playfair's Works, vol. iv. p. 78; "Illustrations of the Huttonian Theory," p. 213.

† The true generic affinities of many of the upper Devonian fishes have still to be determined. At present it is impossible to say with certainty to what fish the remains mentioned in the text may have belonged. Mr. Stevenson of Dunse was the first, I believe, to detect fish-remains in these sandstones (see his paper on Cockburn Law. Trans. Roy. Soc., Edin., vol. xvi. p. 33). They have also been obtained in considerable quantity by Mr. Gibbs and myself during the progress of the geological survey of the district.

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met with. But no sooner do we pass up into the grey and purplish sandstones and shales of the Carboniferous group, than these organic remains cease, and their place is taken by others which are recognized as truly Carboniferous. We cannot doubt, therefore, that the red sandstones in question belong to the uppermost part of the Old Red Sandstone series.

Mr. Milne Holme, in his geological description of Berwickshire,* has endeavoured to show that these sandstones are possibly divisible into two groups, one undoubtedly belonging to the formation below the Carboniferous, the other much more recent, and referable perhaps to the "New Red Sandstone." He grounds this statement on the fact that these strata are for a considerable distance (as in the neighbourhood of Billy Castle,) nearly flat, that southwards similar red sandstones occur, inclined to the south or south-south-east, at from 5° to 15°, while not far to the west, at Prestonhaugh, they are violently contorted. He infers, therefore, that the inclined series dipping below the Carboniferous strata belongs to the Upper Old Red Sandstone, while the flat portion may be more recent than the Carboniferous beds, and hence may even be as late as the Permian or Trias. But the difference of inclination between the Billy sandstones and those near Chirnside is not more marked than between contiguous portions of the neighbouring Carboniferous beds, and seems to be of itself much too slight to justify so important a sub-division. Besides, the lithological character of the whole series, whether horizontal or inclined, remains uniform throughout. I believe the same fossils have been found in the one set of strata as in the other. At the same time there seems good reason to surmise that an unconformity does exist in the Upper Old Red Sandstone of the south-east of Scotland. The rapid disappearance of the vast conglomerates of Dunbar and the Eastern Lammermuirs, and their replacement by the trifling band of red sandstone at Cockburnspath, are perhaps to be explained by an actual physical break in the succession of beds belonging to this division of the Old Red Sandstone. I shall enter upon the discussion of this question in the Memoir to accompany Sheet 33 of the Geological Survey of Scotland.

The basement beds of the Upper Old Red Sandstone as developed in this district are best exposed along the banks of the Whiteadder at Cockburn Mill. No better section could be desired to show the relative ages of the Silurian grits, the granite, the red sandstones, and the veins of greenstone. We gain some insight too into the aspect of the shore along which these sandstones were deposited, and into the character of the fish which lived at the time, and of some of the plants that clothed the neighbouring land. The river has cut its way down through the red beds, and laid bare the surface of Silurian rock, from the waste of which, the conglomerates and sandstones were formed. We see these old reefs and ledges standing out of the waters of the Whiteadder, just as they must have stood out of the waters of that ancient lake or sea, by whose waves their shingly ruins were slowly piled up around and over them. And the shingle is there still; its angular and rounded pebbles heaped together on every projecting point of rock, as they were left by the last wave that broke among them. They are now no longer loose, but bound up in a stiff red paste, from which the pebbles everywhere protrude. A little further up, the pebbly beds rest directly on the granite, of which they contain fragments, but both here and further down the river, they have undergone a good deal of

* Trans. High. Soc., vol. xi. p. 206.

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squeezing and fracturing since the time of their deposition, so that their junctions with the older rocks are sometimes not so clear as could be wished.*

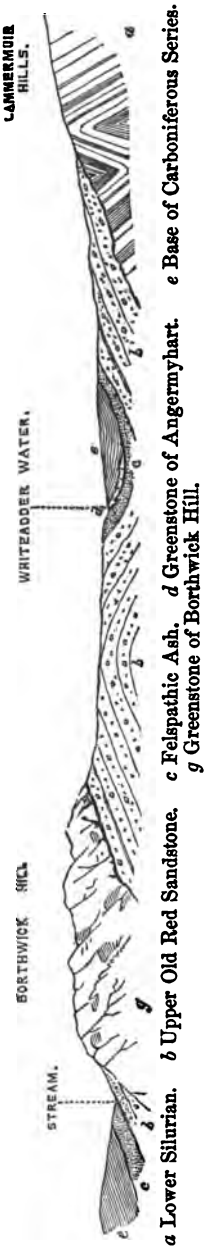
LAMMERMUIR HILLS.
WHITEADDER WATER.
BORTHWICK HILL
STREAM.
a Lower Silurian. b Upper Old Red Sandstone. c Felspathic Ash. d Greenstone of Angermyhart. e Base of Carboniferous Series. g Greenstone of Borthwick Hill.

Fig. 6.
Sketch-Section from Hardens across Borthwick Hill to the Lammermuir chain above Primrose Hill.

The lower beds of the red sandstone series consist of alternations of breccia, conglomerate, red sandstone, and marl. Where they rest on the underlying rocks, they are made up of angular and rounded fragments of Silurian grit, shale, and granite. Bands of pebbly red sandstone with well-preserved ripple-marks succeed, dipping in a south-easterly direction at about 23°. Among these lie pebbly and brecciated beds, sometimes full of felspathic balls derived from the neighbouring hill. Layers of red marl next make their appearance among the pebbly sandstones and finer conglomerates. A good deal of faulting and contortion of the beds has taken place here; and a dyke of light reddish-coloured amygdaloidal greenstone may be seen traversing the beds. It is at this point, between the dyke and Cockburn Mill, that the fish scales occur. They lie in a red marly conglomerate, and are only in a fragmentary state. At the little cottage of Prestonhaugh red fissile sandstones with ripple-marks and seams of sandy marl are seen in the bed of the Whiteadder, dipping first east by north, and then turning round towards the south-east at 18°. Some coarse shingle now occupies the bed of the stream, but at the foot of the high wooded banks on the south side of the river-course, highly inclined Silurian rocks again make their appearance. These can be traced along the bank in a north-westerly direction, until at the foot of the Birkenside Burn they join the main Silurian mass of the Lammermuir chain. They form in short a long tongue of Silurian strata running out into the red sandstone series. Their south-eastern extremity, as shown in the bed of the river, is overlaid by some red sandstones and marls dipping down the stream at 17° to 20°, and containing numerous fragmentary scales and plates of the same fish which occur at Cockburn Mill. As the beds are traced eastward they become more steeply inclined, the angle rising even to as much as 60°, while several distinct fractures may be seen running across them. At the east end of the section here laid bare, the beds have a S.S.W. dip at 27°, so that there is probably not a little squeezing and displacement.

Nothing further is exposed along the river until, at the bend due south from Primrose Hill, a bed of green felspathic ash occurs. This volcanic rock forms here the boundary between the

* See Mr. Stevenson's paper, already cited.

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Upper Old Red Sandstone and the basement of the Carboniferous series, for immediately to the east it is covered in regular sequence by white and greenish sandstones and shales, with well-marked carboniferous plants. The amount of shingle in the Whiteadder throughout this part of its course tends in some degree to obscure the general relations of the rocks. But all doubt of the order of succession is removed by a visit to the stream which descends from the Hardens Hills to the south-west of Dunse Law and Borthwick Hill. The red and grey sandstones which there form the top of the Upper Old Red series, are seen dipping towards the south-east at a point about 650 yards to the N.E. of the farm of Hardens. Above them comes a band of reddish felspathic ash distinctly stratified with red sandy layers and balls of whitish sandstone. The ash is succeeded by some grey sandstone and black sandy shale full of plant-remains, and undoubtedly belonging to the carboniferous group. On both sides of the great semicircular ridge of Dunse Law this ash-bed is thus seen to occupy the same position. It appears to be wanting, however, between the two localities; at least it is not seen sweeping round by the town of Dunse, and hence the original point of connexion between the bed in the Whiteadder and that in the Hardens Valley has been removed by denudation. The rock certainly does not reach far to the east, for in the Cumledge Burn and in the transverse sections laid bare by the streamlets that fall into the Whiteadder from Billy Burn, it is wholly absent. As developed in the Whiteadder near Primrose Hill, it is a greenish felspathic rock, full of angular and more or less rounded fragments of greenstone and Silurian grit. A bed of columnar porphyritic greenstone, with an easterly dip and a remarkably scoriaceous aspect in some parts of its mass, lies in the ash, forming the picturesque crag at Angermyhart. A smaller and much less observable patch of light-coloured highly amygdaloidal and porphyritic greenstone occurs in the ash a short way further down the stream. Owing to a bend of the Whiteadder at this point, the ash quits the channel, and runs on southward, while the white and greenish sandstones at the bottom of the carboniferous series are exposed dipping away from the ash, first in a north-easterly direction and then due north, as the whole of the beds trend round again towards the river. By this change in the direction of dip, the ash is again exposed on the south side of the water close to Preston Bridge. The red sandstones which underlie it are seen on the steep bank, while a greenstone which lies above it forms the foundation for the southern limb of the bridge. Immediately beyond this, in the bed of the stream, the white and yellowish sandstones containing plants are again seen, and from this point the whole of the rest of the course of the Whitadder runs upon strata of carboniferous age. The greenstone of Preston Bridge occupies certainly the same position as that at Angermyhart, but they do not appear to be continuous. From the bridge, however, the rock seems to extend to Cumledge Burn, for in the ravine of that streamlet the red sandstone series is separated from the carboniferous sandstones and shales by a bed of greenstone, the strata above and below which dip N.E. at from 32° to 40°. This rock towards the bottom is of a purplish fine-grained texture, and full of joints, whose surfaces are coated with serpentine. Higher up a marked amygdaloidal structure is observable, the cavities being to a considerable extent filled with green earth. Between the point where this greenstone crosses the burn, and the margin of the Whiteadder carboniferous sandstones occupy the rest of the ravine.

From Preston Bridge eastward the boundary line between the Old Red Sandstone and the overlying formation runs parallel to the Whiteadder, and is here and there cut across by the streamlets which descend on the north side of that river. No very clear sections of the passage

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beds, however, occur in any part of this tract. The streams which best expose the rocks are those in the neighbourhood of Foulden, but even there some obscurity exists, arising partly from occasional patches of drift and soil, and partly from the high inclination and fractured state of the strata. Yet the general relation of the red sandstones below to the white, grey, and yellowish sandstones and variously tinted shales above cannot be missed. The palæontological differences between the two groups of strata, though comparatively slight, can yet be detected along this line. Thus in the red sandstones of Harelaw Quarry rugose plates and scales of those holoptychius-like ganoids of the Upper Old Red Sandstone occur,* to which reference has already been made, while due south from this locality, in the carboniferous shales on the banks of the Whiteadder at Huttonhall Mill, scales of the characteristic Lower Carboniferous *Rhizodus Hibberti* may be obtained.

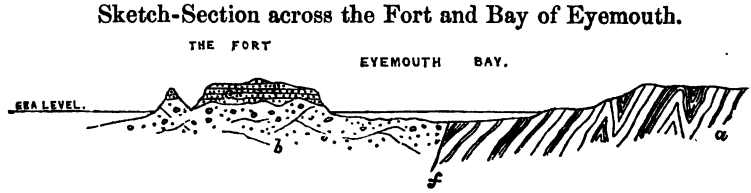
A reference to the Map will show the great variation in the thickness of the band of Upper Old Red Sandstone. The beds must have been deposited on a very uneven bottom, and in a descending area. Hence, outlying patches now occur scattered over the older rocks at much higher levels than those of the strata just described. There is, in short, good evidence to show that the whole of at least the eastern part of the Lammermuir chain was covered at one time with the conglomerates and sandstones of this formation. To this day the conglomerate ascends to a height of 1,345 feet above the sea in Monynut Edge (Sheet 33). Whence we may safely infer that it once extended eastward over the lower grounds. That it reached away out into the area now occupied by the German ocean is proved by the denuded cliffs of red sandstone and conglomerates at Cockburnspath, and by several outliers scattered over the high grounds that border the sea from St. Abb's Head, almost as far as the gates of Berwick.

It is these outliers which now fall to be described. They are seven in number, exclusive of the one on the Cockburnspath shore. Beginning at St. Abb's Head, and proceeding in a south-easterly direction, the first that we encounter is the patch of conglomerate previously referred to as forming Bell Hill. It lies on the edges of the Silurian and Lower Old Red Sandstone ashy strata, in an oblong ridge with a length of about 600 yards, and a breadth of 350. At its south-eastern margin it overhangs the cliff of Halterem's Loup, the base of which is washed by the waves. The rock of this outlier is a conglomerate, sometimes approaching a breccia, made up of fragments of the underlying Silurian grits. Measured at Halterem's Loup it somewhat exceeds 150 feet in depth, its base being there about 100 feet above the sea, while the summit of Bell Hill is 257 feet.

The next outlier is that which caps the north-western promontory of Eyemouth Bay, on the headland called the Fort. It consists of a well-

Fig. 7.

Sketch-Section across the Fort and Bay of Eyemouth.



a Lower Silurian Grits and Shales. *b* Lower Old Red Sandstone Ash and Felstone.
c Upper Old Red Sandstone and Conglomerate. *f* Probable Line of Fault.

* A fine specimen of *Bothriolepis ornata* was obtained from this quarry by the Geological Survey.

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marked conglomerate, sometimes more or less brecciated, derived chiefly from the waste of the felspathic rocks on which it rests. Its junction with the underlying masses is well seen along the side of the cliff, especially on the north, where the sea by scooping out deep narrow creeks, has isolated portions of the felstone into rude sea-stacks, which stand up with a capping of conglomerate. The surface of the felstone on which the derivative beds repose is worn and uneven, and must evidently have been so previous to the deposition of these beds. No one can doubt, even though the felstones show no trace of bedding, that the conglomerate covers them unconformably and belongs to a much later age. These conglomeratic strata have a gentle dip to the north, so that while on the south side of the fort their base rests on the top of the cliff, at the north side they descend into the sea. They are there well exposed in flat ledges between tide-marks, while a little further west they may be seen picturesquely capping an isolated stack of the underlying igneous rocks. Some parts of the series are remarkably firm and compact, insomuch as to be used in the construction of the Eyemouth harbour, as well as in several houses and walls.* It is not a little curious to see along the sides of the pier these blocks of conglomerate, made up as they are of mere rounded pebbles, yet able to withstand all the fury of the easterly gales that from time to time burst into the Bay of Eyemouth.

The next outlier to the south is so small and so inaccessible as easily to escape notice. It overhangs the summit of the sea-cliff to the south of Eyemouth at a point called Hawk's Heugh, where the precipice rises to a height of 300 feet above the waves. A dark trap-dyke here runs up the face of the cliff, but on reaching the top it is covered over by a patch of felspathic breccia, derived perhaps from its detritus. Only a few square yards of this breccia are visible, lying on the declivity that slopes northward from the highest part of the cliff at Bleak Heugh.

In the glen of Burnmouth, where its north side forms a steep bank between the bend of the Partanhall road and the space immediately above high-water mark, lies a small patch of what is probably a conglomerate of the same age as those just described. It adheres to the side of the hill and consists of a mass of angular fragments of grit and felstone of all sizes cemented in a reddish clayey paste. It bears a close resemblance to the conglomerate outliers of Lamberton and Scuddylaw. It is possible, however, that this mass of angular débris has been derived in later times from the decomposition of the overhanging rocks. A few yards higher up, in the bottom of the ravine, there are two blocks of a breccia which consists of angular fragments of pink felstone cemented by calcareous tufa. The fragments may have been derived from some of the felstone dykes which traverse this glen, though I saw no calcareous incrustations now in progress in any part of this locality.†

Perhaps the most striking outlier in the whole district, so far at least as its position is concerned, is that which clings to the side of Chester Hill about half a mile south from Burnmouth. It looks out upon the sea from a height of 560 feet, the bared ends of its pebbly strata rising towards the north-east, and pointing with a significance that cannot be mistaken to the enormous denudation which this part of Scotland has undergone since the deposition of the Upper Old Red Sandstone. Along the precipice which forms the north-east side of Chester Hill these

* Mr. Milne Home, writing in 1835, remarks that the sea wall of the harbour, which was built out of this conglomerate, had not needed repair for the preceding fifty years.

† See Milne Home, Trans. High. Soc., xi. p. 225.

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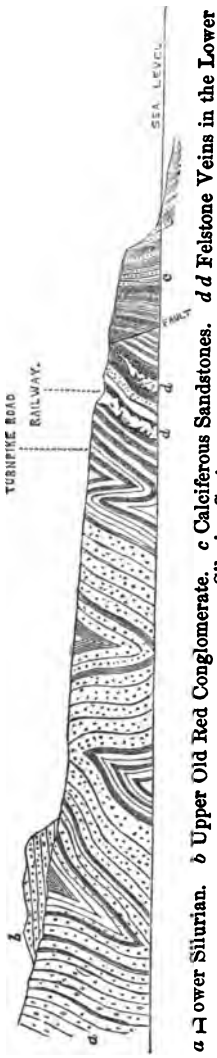

Fig. 8.
Section from Chester Hill to the beach south of Burnmouth (on true scale, 6 inches to a mile).
a Lower Silurian. *b* Upper Old Red Conglomerate. *c* Calciferous Sandstones. *d d* Felstone Veins in the Lower Silurian Series.

strata are clearly exposed. Sandy and well-bedded in the lower layers, and dipping W.S.W. at 8°, they become in the upper part a coarse brecciated conglomerate consisting of fragments of Silurian grit and felstone. Owing to the depth of soil to the west and south, the area occupied by this outlier can only be approximately ascertained. It probably does not cover a space of more than 550 or 600 square yards, and its visible thickness is perhaps about 70 or 80 feet.

The next outlier occurs rather more than a mile to the south-east. It caps the cliff overhanging Lamberton Fishery, and has been cut through by the railway. It consists of a very coarse brecciated conglomerate entirely derived from the grits, shale, and felstones of the Silurian series on which it rests. At the north end it contains some well-stratified beds of pebbly sandstone, but with this exception there is a singular absence of stratification, the included fragments of all sizes being heaped together like the boulders in some parts of the Boulder Clay. So strong indeed was the resemblance of this conglomerate to parts of the Drift, that I examined carefully the surface of almost every pebble and stone exposed for some yards along the Railway section, in the hope of finding some of them covered with striations. But the search proved unsuccessful. On the top of the bank lies a thin layer of drift gravel, in which the boulders, chiefly derived from the underlying conglomerate, are frequently covered with ordinary glacial striæ. But as soon as we penetrate downward into the palæozoic rock these striæ disappear. The conglomerate boulders are very generally covered with a greenish or reddish glaze, which can be scratched with the nail, and is of the same argillaceous character as the general matrix. At the head of the little bay at Lamberton Fishery, a mass of beautiful flesh-coloured porphyritic felstone, in the Silurian series, is covered by this conglomerate, which indeed is largely made out of its detritus. So that here, as well as over many parts of this district, there is demonstrative evidence that the pale porphyritic and quartziferous dykes and bosses in the Silurian strata belong to a more ancient era than that of the Upper Old Red Sandstone. It will be seen from the map that the great fault already alluded to skirts the eastern margin of this patch of conglomerate, and separates it from the highly inclined sandstones of the Carboniferous series.

The last and probably the largest of all the outliers of this formation shown on the present Map is that which flanks the Silurian hills between Marshall Meadows and the Steps of Grace. The extent of its area, owing to the drift-covered character of the ground, cannot be exactly ascertained.

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But it is well exposed in the ravine between the Berwick Water-works Reservoir and New East Farm. Throughout a great part of its mass it closely resembles the coarse brecciated unstratified conglomerate of Lamberton. Its included fragments are often quite angular, and of considerable size, especially in the lower parts of the stream. Higher up they are of smaller dimensions, and assume a more bedded aspect, the strata dipping at a high angle in an E.N.E. direction. Silurian grits occupy the bed of the water-course before we reach the Reservoir. From the steep inclination of the conglomerate, it must have undergone considerable disturbance since its deposition, and in this respect may be compared with the highly-tilted sandstones of the Whiteadder at Prestonhaugh. The eastern edge of this outlier, like that of Lamberton, is bounded by the same long line of dislocation.

In conclusion, the position of these outliers renders it probable that the whole of the eastern part of Berwickshire was at one time covered with strata of Upper Old Red Sandstone age. Their coarse brecciated and unstratified character at Lamberton and Marshall Meadows indicates an origin different from that of ordinary water-worn sediment. Possibly ice may have had some share in the production of a mass of detritus which so closely resembles parts of the Boulder Clay, or it may be that these conglomerates represent the results of a subaerial waste, of which the products were accumulated, without suffering much from wave-action, along the margin either of lakes or of the sea.

CHAPTER VI.

Carboniferous Formation.

The band of Old Red Sandstone which flanks either side of the Lammermuir chain passes up into the sandstones and shales of the Carboniferous group. On the north-west side we see the gradation well exposed along the shore at Cockburnspath, but this small area, as already explained, comes more appropriately into the Memoir descriptive of Sheet 33. The passage beds between the two formations along part of the southern margin of the hills, and also a considerable portion of the lower members of the Carboniferous series, are shown on the present Map. These strata occupy the southern edge of the Map, extending down the course of the Whiteadder from Preston Bridge to the sea. Owing to the large fault, which runs N.N.W. from Berwick, they are also prolonged on the coast as far as Burnmouth. No outliers occur in any part of the district.

Arranged in descending order, the succession of Carboniferous strata is as follows :—

Base of Carboniferous Limestone - -	1. Red sandstones with two bands of fossiliferous limestone, and two or three thin coal seams. Total thickness shown on this Map probably under 500 feet.
"Calciferous Sandstones," = Lower Limestone Shales of England.	2. White, yellow, grey, and reddish sandstones, with alternations of green, blue, and lilac shales and bands of "cement-stone." Total thickness perhaps about 3,000 feet, passing down into—
	3. Upper Old Red Sandstone.

*Calciferous Sandstones.**— The series marked No. 2, graduating

* This term was originally proposed by Mr. Charles Maclaren to include the great group of beds which in the Basin of the Forth are intermediate between the Carboniferous limestone and the top of the Old Red Sandstone. The name has not been generally adopted; but in working out the geology of Central Scotland I have found

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upward from the Old Red Sandstone, is that which falls to be first described. Its base is seen in the Whiteadder at Preston Bridge, in the Cumledge Burn, in Billy Burn, and in several of the streams which descend into the Whiteadder from the high ground between Chirnside and Mordington. These lower beds consist of white and reddish sandstones, sometimes with partings of clay or shale. They not uncommonly contain fragments of calamites, and fern-stems of recognizable Carboniferous forms. Bands of coarse argillaceous limestone, or "cement-stone," as it is termed, occur in this undermost part of the Carboniferous system, as at Ninewells, near Chirnside, and in the streamlet between Mordington Bridge and Edrington House, but they become more abundant higher up in the series.

The sandstones at the bottom of the group pass up into a remarkable series of sandy shales in rapidly alternating bands of various shades of green, grey, blue, and a kind of lilac colour. Ordinary black argillaceous shale is of rare occurrence. In these respects the lower Carboniferous strata of Berwickshire are strongly marked off from those on the north-west side of the Lammermuir chain, where such shales as those of the Whiteadder sections are absent. They contain frequent bands of sandstone, often full of Carboniferous plants, and also numerous seams of an impure, sometimes nodular, limestone or "cement-stone." Gypsum also occurs in partings between the shales, as along the south side of the Whiteadder, near Allanton, while according to Mr. Milne Home, some of the springs which rise through these strata contain an appreciable quantity of salt. This alternating series of shales, sandstones, and limestones is laid bare in many fine sections along the course of the Whiteadder; those at Chirnside Bridge, Allanton, Edrington Mill, Hutton Mill, and Edrington Castle, and those in the tributary streamlets between Foulden and Mordington, may be especially noticed. To one who has familiarized his eye with the character of the Lower Carboniferous strata of the Lothians and Fife, there is something altogether peculiar in those of Berwickshire. Among the latter, he misses the massive deposits of white sandstone which form so marked a feature at Dunglass, Craigleith, Binny, Cullalo, and elsewhere. He fails also to detect such thick zones of finely laminated black shale as occur at Wardie and Queensferry; indeed he can hardly detect any black shale at all. While in the Lothians, the prevailing character of the strata is marked by thick bands of white, yellow, or grey sandstone, separated by beds of black shale, often of considerable depth; in Berwickshire the strata are individually of much less thickness; they alternate rapidly with each other; so much so, that some of the sections almost remind one of the finer alternations of the Lias. They are, moreover, usually pale in colour, and more or less sandy throughout, fissile bituminous shale being, so far at least as I have observed, almost entirely wanting. The shales, in short, very commonly deserve the name of sandy marls or mudstones. The Berwickshire series differs further from that of the Lothians in the great abundance of its thin limestone bands. In the latter district, limestone is by no means uncommon, but it occurs for the most part in widely separated beds of seldom less, and usually more, than a foot in thickness, and it is commonly of a compact, semi-crystalline, almost horny texture. In the Berwickshire area, the

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it so convenient that I have used it for some years. Nor is its local convenience its only recommendation. Seizing the occurrence of bands of cherty limestone as a distinguishing stratigraphical feature, it serves to link together a great natural group of strata in the Lothians and Fife, and enables us to put these in parallel with the corresponding portion of the Lower Carboniferous series of England and Ireland.

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limestones are of a grey or yellowish tint, of a dull earthy texture, usually only a few inches thick, and they succeed each other so quickly that sometimes a dozen seams or more may be counted in one river-cliff.

I have reserved for more detailed description the section which has been laid bare by the waves on the coast at Burnmouth. Here a depth of 2,500 feet of strata may be examined, from the lowest limestone of the Carboniferous Limestone group down to the beds which abut against the great fault. We do not see at this point the base of the series, for the effect of the dislocation has been to throw it out; nor is it possible to estimate exactly the amount which may be absent. I do not believe it exceeds a depth of 500 feet, which may be supplied from the Whiteadder sections. Taking the section as it stands, we find that its strata, owing to the fault, are nearly vertical throughout. Those nearest the fault are actually reversed, so as to dip in a westerly direction at an angle sometimes as low as 55°. Between the village of Ross and Ross Point they become vertical, and then incline at high angles towards the east. Hence the length of a horizontal section, measured across the edges of the beds at a right angle to the strike, very nearly represents their actual thickness. They run in long parallel courses, the harder sandstones forming lines of reef along the shore, while the softer marly beds are occupied by pools of sea-water, or covered with tangle and stones.

Beginning then at the beds which seem to dip at the fault behind the village of Burnmouth, we meet with some bands of reddish white and grey sandstone, separated by zones of greenish and reddish marly shales. The latter are occasionally of a dark grey colour, and contain fragmentary plants, *spirorbis carbonarius*, and scales of *amblypterus* and *palæoniscus*. These strata are well exposed on the steep bank overhanging the harbour, and also on the beach at the pier. There the marly shales, with their associated seams of cement-stone, are seen graduating into shaly sandstones, followed by some distinct bands of white sandstone with shale-partings, on which the Burnmouth houses are built. The zone of marly shales which succeeds contains a thin seam of impure limestone (full of *anthracomya, Edmondia,* &c.), which may be traced along the shore, its vertical edge forming a narrow and scarcely perceptible ridge in the softer strata, until it ascends the cliff at the west end of the village of Ross, where its weathered surface exposes its fossil contents.

From this limestone a continuous ascending section can be examined eastward, both along the face of the cliff and on the beach, up to the base of the Carboniferous Limestone. It consists of the same alternation of green, grey, and reddish mudstones, or marly shales and cement-stones, with bands of hard grey, reddish, and white sandstone. These mudstones exhibit here, in a characteristic way, the features which distinguish them from the ordinary shales of the Carboniferous group of the Lothians. They are exceedingly fine-grained, compact, shivery, breaking into the rudely spheroidal nodules, and with the semi-conchoidal fracture peculiar to such bands of non-fissile argillaceous matter. They rapidly alternate in beds of varying colours and hardness. Sometimes thin partings of sandstone, from two or three lines to two or three inches in thickness, occur in the marl. Such interruptions, however, are not frequent; the strata are mainly argillaceous, though they often become sandy in texture and full of mica, especially in the greenish bands. Thin veinings of gypsum occur sometimes parallel and at other times oblique to the planes of bedding. These strata, whether marls, cement-stones, or sandstones, are, as a whole, singularly destitute of fossils.

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I cannot quit the description of this group of strata without alluding to one of the best inland sections in which they are displunged. It occurs at a bend of the Whiteadder at Raven's Knowe, about a mile due south from Mordington Church. A thick mass of sandstone, forming the eastern bank of the river on which the ruins of Edrington Castle stand, begins in its lower part to be seamed with layers of grey and dark red ferruginous marly shales, and then it slowly passes down into a thick shaly or mudstone series, like that along the Whiteadder at Edrom and Chirnside, or like parts of the Burnmouth coast-section. This set of beds consists for the most part of a dull grey sandy mudstone, arranged in thin bands from a foot or so in thickness down to the merest films. Some bands contains numerous plants, others of the sandier kind are full of vertical worm tubes, while some abound in cyprides and the little *spirorbis carbonarius, anthracomya,* and fragments of *Rhizodus Hibberti.* Pale yellowish bars of a fine shivery mudstone, others of an earthy cement-stone, run along the cliff. Towards the base of the series green and purplish tints become conspicuous, the beds there are thinner, and the different tints alternate more rapidly. Seen from a little distance nothing can be more striking than the perfect ribbon-like regularity of the bedding of these pale grey and yellowish strata, and the sharpness with which it is marked off by the alternating colours. The section has a strong resemblance to those vast groups of calcareous lacustrine strata which are laid open in the numerous river-courses round Le Puy en Velay in Central France.

More may be expected to be known of the origin and fossil contents of this series of rocks when the remainder of the great Berwickshire plain comes to be examined in the course of the Geological Survey. At present the best continuous section with which I am acquainted is that of Burnmouth, but, as above explained, the base of the series is there wanting. If we proceed from the basement beds, as shown in the Whiteadder, we cannot, owing to the undulating nature of the strata and the direction of the river-course, obtain a greater thickness in any continuous sections than about 1,200 or 1,300 feet. That is the probable depth of strata along a line drawn from the Old Red Sandstone, at Foulden Bridge, to near Paxton. The section down Foulden Burn from Foulden Mill to Hutton Bridge shows a depth of strata of about 800 feet. From the same Old Red Sandstone boundary, at Cruicksfield, to the bank of the Whiteadder, at the head of Blanerne Haugh, there is a thickness of about 500 feet. So that along the whole course of the Whiteadder, notwithstanding its numerous cliff-sections, the actual depth of Carboniferous strata falls considerably short of 1,500 feet. Of these strata the lower parts are wanting in the Burnmouth section. It seems probable, however, that before we have advanced more than 500 or 600 feet upward from the base of the formation, as shown in the localities in the valley of the Whiteadder, we begin to meet with the lower parts of the Burnmouth series. If this be true we cannot add more than about 500 feet to that series, and this will give a total of 3,000 feet as the thickness of the Calciferous sandstones, or that lower part of the Carboniferous formation which underlies the Carboniferous Limestone, and represents the Lower Limestone shales of the English counties.

Carboniferous Limestone.—At Hilton Bay and Lamberton the highly inclined strata which extend eastward from Burnmouth are overlaid by a band of limestone, full of *lithostrotion, productus giganteus,* &c., which may be taken as the base of the Carboniferous Limestone group, seeing that it serves to divide two groups of strata very distinct lithologically, and even capable of separation by a comparison of organic

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remains. Resting on this bed as a base line lies a thick series of red sandstones, with one or two coal seams in the lower part. These are overlaid by a group of limestones, dark shales, sandstones, and coal seams, of which the lower members occur along the shore at Berwick. But this part of the coast-line is traversed by numerous faults and curvatures of the strata, which are beautifully shown on the beach. Hence the detailed order of succession cannot be made out until the limestone series of Northumberland, where the whole order is well exhibited, comes to be worked out in detail. In the meantime the lower part of the Carboniferous limestone of this district may be classified in descending series, thus :—

A thick group of limestones, shales, sandstones, and thin coals, seen at Meadow Haven, and between Berwick Pier and the King's Mount, whence they undulate northwards to the Sharper Head, and southward into the English Border.

Red sandstones and bands of shale seen in horizontal beds along the coast cliffs from Sharper Head northward to Lamberton. Thickness fully 100 feet.*

Lamberton limestone, 1 to 3 feet thick, full of carboniferous limestone fossils. Below this bed comes the thick series of sandstone and marl already described as the equivalents of the Lower Limestone Shales.

The Lamberton limestone is usually a dull brownish yellow or reddish iron-stained rock charged with bunches of *lithostrotion junceum*, *chætetes tumidus*, *alveolites depressa*, *productus giganteus*, and other characteristic fossils. As shown in the little gully behind the fishing station, it consists of two bands with at least two seams of coal. But the proximity of the great fault and the quantity of debris which covers the declivity tend to obscure the rocks below. In Hilton Bay the strata are well shown, both on the beach and in a prominent cliff which here protrudes its wasted rocks into the ocean. We see how the fault by which these carboniferous deposits have been depressed has not only tilted them on end, but has actually reversed their inclination, so that the upper surface of one bed rests on the under surface of its neighbour. That this is the true arrangement cannot be better shown than by the band of limestone which runs out as a reef in the centre of the bay. For if this bed be examined it will be found that the bunches of coral are all lying with their roots upward, a position which is only explicable by admitting that the bed itself has been turned over. East from this only a few yards the strata are quite vertical, and then in the outstanding cliff just alluded to they right themselves with remarkable rapidity, so much so that at the seaward end of the cliff the inclination is no more than about 8° or 10°. (See sketch section engraved on the Map.)

The Lamberton limestone rests on coal, and another coal-seam occurs a few feet lower down. But these seams are not of sufficient value to repay the cost of extraction. Several pits have been sunk to them, and ingoing eyes may be seen at different places along the coast, as at Marshall Meadows Bay and Megs Dub. Mr. Christie, the last tenant who tried to work these coals, and to whom I applied for information regarding them, wrote me as follows :—"You will observe," he says, "a thin coal in the face of the rocks, near the sea mark, opposite "where the pits were sunk. I drove a level in that coal up to the "eastmost pit, and sunk the pit about 20 fathoms to the coal below,

* It is, I think, this zone of red sandstone which, sweeping to the south-west of Berwick-on-Tweed, forms the prominent ridge to the south of the river at Longridge, Shoreswood, &c.

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" which latter was the only coal we wrought. The seam was divided " into two leaves as follows :—

	ft.	in.
Rough coal - - - - -	1	8
Fire clay, very fine in quality - - -	2	0
Hard coal - - - - -	1	4
Total thickness of working - -	5	0

" There was no other seam but this wrought on the ground, and as it " had a fire-clay roof of about 6 feet, it was a very troublesome and " expensive coal to work. The quality was also inferior, the thick " leaf being mixed with sulphur ; in short, the whole concern turned " out so unprofitable that it had to be abandoned after a considerable " outlay of money. To the west [north] of the colliers' houses, in a " field half-way betwixt the turnpike road and the railway, a yellow " limestone of about 4 feet thick was found and opened up. It proved " to be of good quality, but as the seam did not hold regular, it was " also given up."

There is a belief in the district that these Lamberton Coals overlie those of Scremerston, and that if the pits were sunk to a sufficient depth a valuable coal field might be opened up. But there could hardly be a greater error. The Scremerston seams lie up among the limestones of which the lower part is seen at Berwick, while those of Lamberton lie associated with the very lowest limestone of the series. No pit, therefore, could by any possibility reach the Scremerston Coals at Lamberton.

There is another misconception, not confined to this district, but common among geologists, that these Berwickshire Coals lie below the true Carboniferous limestone, and so differ from even those of the north of England. This however is disproved by the fact that they lie along with a limestone full of the characteristic fossils of the Mountain Limestone. They do not therefore differ in position from the edge coals of Midlothian, or the coals which throughout the whole of central Scotland occur at the base of the Carboniferous Limestone series. So far as I have yet observed the strata below that series in Berwickshire do not contain coal.*

Advancing southwards from Lamberton along the coast-line we find that the fault retires from the sea, and then runs nearly parallel to the shore at a distance varying up to three quarters of a mile. By this means the strata are allowed to range along the sea margin in beds almost completely horizontal—a position which has given rise to a line of steep indented cliff of nearly uniform height. The Lamberton limestone thus runs along the face of the escarpment, following all the sinuosities of the coast-line for upwards of two miles. It is especially conspicuous in the magnificent cliff of Marshall Meadows Bay, which rises perpendicularly for 150 feet from the beach. (See section on Map.)

The soft shaly strata below the limestone have in some places been undermined, and the overlying red sandstone has slid down in huge masses upon the shore. At St. John's Haven the limestone descends to the beach, where its surface has been well exposed by the surf. From this point the remarkable group of red sandstones which separates this limestone from those of Berwick occupies the whole of the cliff. These

* Mr. Milne Home refers to several instances of an unsuccessful search for coal in the calciferous sandstone group of Berwickshire. Trans. High. Soc., xi. 199.

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sandstones are full of false-bedding and have a rich red tint mingled with bars and streaks of a golden yellow. They weather out into every conceivable form of cleft, and cave and creek, basin and skerry, and sea-stack. The process of waste among such strata forms a subject of study by itself, and nowhere could it be more advantageously pursued. We see here how sea and air, frost, and rain and springs have acted together in wearing away the rocks, and how their agency has sometimes been accelerated, sometimes retarded, by the structure of the rocks themselves; how the waste has gone on rapidly along joints and bedding planes, splitting up the rock into so many fantastic shapes, and how the fragments that have been detached from the cliffs, by becoming lodged among the ledges below, have been ground into rounded boulders, which have thus eaten their way downward and scooped out for themselves deep and wide cauldrons filled to the brim with clear green water, and each a little world peopled with the plants and animals of the sea.

About half-way between the perforated cliff called the Needles Eye and the deep creek known as Brotherston's Hole, a thin band of coarse red sandy limestone occurs among the sandstones. It seems to die out northwards, and its southern extension cannot be traced owing to the intervention of a small fault. It is covered and underlaid by a few feet of light grey sandy shale, with *sphenopteris* and other plants. From this fault onward by Brotherston's Hole the sandstones again occupy the whole cliff, their false-bedded strata weathering out as usual into picturesque and varied outlines. At the bay of the Burgess Cove, however, an important dislocation takes place. It runs in a W.S.W. direction towards the new Burial Ground, and its effect is to bring in some of the lower greenish sandy marls, sandstones, and bands of cement-stone, such as occur near Burnmouth. These strata dip in a W.S.W. direction, undulating at about 5° to 8°. After occupying the cliff and beach for about 280 yards another fault runs in a parallel direction, with the effect of bringing down some red and white sandstones. These are laid bare on the beach, and also along the cliff, which has now greatly diminished in height.

I believe that these sandstones, which run round the promontory of Sharper Head, are the upper portion of the Burnmouth series, and that the limestone which covers them is a prolongation of the limestone of Lamberton. But in this I may be in error. Hardly have we turned southward round the Sharper Head than another fault runs across the coast-line in a W.N.W. direction. On crossing it we find ourselves at once among the Berwick limestones and shales.

It is from this point that the Carboniferous limestone group can be consecutively traced up through the workable coals. But the description of these strata remains as the subject of a future Memoir.

CHAPTER VII.

Igneous Rocks later than Upper Old Red Sandstone and Carboniferous Formations. Faults.

Reference has been made in Chapter V. to certain beds of ash and greenstone, the date of which must be assigned either to the close of the Old Red Sandstone or to the beginning of the Carboniferous period. They are truly interbedded or contemporaneous volcanic rocks. But associated with both the formations just named, there are found in Berwickshire a number of greenstone dykes and bosses of an intrusive

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character, the date of which cannot be more nearly ascertained than that they are in some cases later than the Mountain Limestone of this district, later even than some of the dislocations by which the Mountain Limestone is traversed. Although, for the sake of convenience in description, these intrusive rocks are here classed together, it is not in any way assumed that they all belong to one geological period. On the contrary, it is quite possible that some of the dykes and masses in the Upper Old Red Sandstone may be of earlier date than the Carboniferous system. This seems by no means unlikely in such a case as that of the great greenstone masses in the neighbourhood of Dunse. We know that this locality was a focus of volcanic action at the close of the Old Red Sandstone period, as shown by the ash of the Whiteadder and of the Hardens Valley. Hence the basalts and greenstones which now cap Dunse Law, Chapel Hill, and the long back of Borthwick Hill, may possibly have been ejected among the Old Red Sandstone strata before any part of the Carboniferous group had been laid down in this part of the country. I shall notice first those igneous dykes and bosses which occur only in the Upper Old Red Sandstone, next those which traverse parts of the Carboniferous series.

At the lower left-hand corner of the Map a mass of greenstone is shown on the west side of the pond in the park of Dunse Castle. This is the eastern end of Borthwick Hill, which runs westward for nearly a mile and a half. Dunse Law is capped with a similar hard black basalt, though, owing to the amount of debris which obscures the sides of this hill, the exact area occupied by the basalt cannot at present be determined. In the same neighbourhood a dyke of a remarkably red ferruginous amygdaloidal greenstone occurs in the sandstone and conglomerate bands of Preston Haugh. It differs from the dark crystalline greenstone of the Carboniferous rocks, and in this respect agrees with all the other greenstone dykes which traverse the Upper Old Red Sandstone of the Lammermuir range. These will be described in the Memoir to accompany Sheet No. 33. Not more than half a mile north from Preston Haugh, a dyke of dark greenstone, weathering out into concentric balls, traverses the granite in the bed of the Whiteadder, and runs westward for nearly a mile and a half. The trend of this dyke is W. 7° S. to E. 7° N., and it will be seen, on comparing the different greenstone dykes on the Map, that this is the prevalent direction, irrespective altogether either of the formation or of the direction of the beds traversed.

The dykes in the Carboniferous strata are well exposed along the coast between Lamberton and the Gull Rock beyond Burnmouth. At the rocky promontory north of Hilton Bay, called Cateairn Bushes, a dyke of greenstone may be seen running in the same W.S.W. direction across the vertical sandstone. It ascends the cliff, adhering to one side like a built wall, and then actually crosses the great fault, without any symptom of being disturbed by the passage. It is laid open in the railway cutting, where it holds on its course across the contorted Silurian strata with their associated felstones. On the shore at Burnmouth an interesting dyke is visible. It consists of a claystone passing into basalt. In the thinner parts of the dyke the rock is a dull granular claystone, weathering with a pinkish grey colour; where the dyke becomes thicker, the central parts pass into a dull blueish sparingly amygdaloidal felspathic basalt. Traced inland, this vein shows a very tortuous course. It disappears in an irregular fissure not far from the N.E. corner of the pier, but a similar rock takes its place in a parallel fissure which continues to within a few yards from the pier, beyond which it ceases to be traceable. The amount of alteration produced by the dyke is very

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slight. The sandstones are in places a little hardened, but the shales continue quite soft and unchanged up to the edges of this igneous rock.

In the glen of Burnmouth a dyke of basalt is seen rising as a wall from near the base of the southern slope, about midway between the top and the bottom of the ravine. Its course is a few degrees north of west, and it traverses the Silurian strata, though possibly it may communicate underneath with the dyke among the Carboniferous beds on the shore.

Less than half a mile further north, the beach is marked by a prominent reef of black rock, rising as a broken ridge from among the barnacled boulders that strew the shore. This is another dyke of basalt, with the usual W.S.W. direction. It is in the central parts a hard blue rock, in places strongly amygdaloidal, but towards the edges it is pale and dull in texture. It varies in breadth from 20 to 30 feet, running across the highly inclined Carboniferous strata in a wavy serpentine course, sometimes abruptly ceasing and then beginning anew. It does not cross the fault, but is confined to the Carboniferous beds, which show but little trace of alteration.

Another dyke of a crystalline greenstone may be traced about a quarter of a mile northward. It descends the cliff among the Silurian grits and shales, and then runs seaward, cutting through two large felstone beds. Whether it enters the Carboniferous series cannot be ascertained, as the coast to the north of this point is entirely occupied by the Silurian rocks. Similar dykes may be seen here and there along the face of the steep cliff which now rises from the sea. One occurs just below the patch of conglomerate which lies on the edge of the precipice at Hawk's Heugh, but it does not reach the sea margin. Again, at the Scout Cave a massive dyke of greenstone traversing the Silurian rocks has at its seaward parts been excavated by the breakers into a deep twilight cavern, the haunt of gulls and rock-pigeons. Some smaller dykes of a similar greenstone may be observed intersecting the grits and shales on the south side of the main mass. Though these igneous intrusions are only seen here among Silurian rocks, I do not doubt that they are, like those of Burnmouth, later than at least the lower members of the Carboniferous series. The same remark probably applies to the greenstone dyke which has been referred to as having insinuated itself among the felspathic and ashy rocks of Coldingham Shore, and to a smaller one which cuts the ash on the east side of Bell Hill.

Faults.—The three most important faults in this district radiate in a southerly or south-westerly direction, from a point in the sea somewhere to the east of St. Abb's Head. It is worthy of note that, in this neighbourhood also, the focus of the Lower Old Red Sandstone volcano appears to have existed. The largest of these faults is probably that which skirts the coast from Burnmouth to Berwick. Its effect has been to depress the Carboniferous against the Silurian series. At Burnmouth it is a low part of the former which is let down next the line of dislocation, but owing to the curvature of that line, the lower members of the Carboniferous are gradually cut off towards the south, so that the beds which abut against the Silurian grits and shales at Lamberton form a portion of the base of the Carboniferous Limestone. Another bend of the fault in the opposite direction allows the lower members to come to the surface again, and they are well shown on the banks of the Tweed below the western outskirts of Berwick. The effects of this fault are prolonged into the Scremerston Coal-field, where the strata along the coast are tilted up, while those in the interior remain undisturbed.

The two other faults separate the Lower Old Red Sandstone ashy

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beds from the Lower Silurian rocks. One has been already described as probably running from Eyemouth in a S.S.W. direction, flanking the high grounds of Lamberton Moor, until it is overlapped by the red sandstones of Edingtonhill. Hence it would appear to be of older date than the Upper Old Red Sandstone. The other skirts the north-west side of the Silurian outlier of Coldingham Bay. It is impossible to determine the extent of displacement produced by these fractures.

Three faults, two of which must be of considerable magnitude, occur in the south-east corner of the Map. The two larger ones run in a south-westerly direction nearly parallel to each other, and their effect has been to let in a strip of the lower or Burnmouth beds among the red sandstones at the bottom of the Carboniferous Limestone series. Until accurate data can be obtained of the succession and thickness of the various members of these lower parts of the Carboniferous series in this district, it will not be practicable to offer any estimate of the extent to which the faults in question have displaced the strata.

The third fault at this locality runs from W.N.W. to E.S.E., and brings down some of the Berwick limestones against the red sandstones at the base of this part of the formation. A good many others of smaller size are seen on the shore between this point and Berwick Pier.

No faults of consequence have been observed among the Silurian districts. The strata there, as already explained, are violently contorted rather than actually fractured and displaced.

CHAPTER VIII.

Drift, Alluvium, Recent Marine Deposits.

The amount of denudation which the district now under discussion underwent prior to the deposit of the boulder-clay, has been very great. The Silurian rocks were probably tilted on end and worn down to a great extent, before the volcanic ashes and conglomerates of the Lower Old Red Sandstone were produced. Along with these later formations, they were still further abraded previous to the laying down of the Upper Old Red Sandstone and Carboniferous series, which are largely made up of debris from the Lammermuir range. It is impossible to estimate the amount of abrasion that went on during the vast interval, here unrepresented, between the Carboniferous Limestone and the glacial beds. Here and there a patch of old red conglomerate and sandstone clinging to a hill-side reveals the fact that by far the greater part, if not the whole of this district, was once covered with these deposits; that they stretched round the Lamberton Hills, across the valley of the Eye Water, and away up among, if not over the valleys and hills of Lammermuir. But before the deposit of the boulder-clay they had been stripped off and left in a fragmentary state. How much of this denudation is to be ascribed to the eroding agencies of the Drift Period, it is now impossible to tell. Leaving this part of the question unsolved, however, we can yet glean some interesting facts relative to the form of the ground in some parts of the district, prior to and during the deposition of the boulder-clay.

As the different Drift-deposits, to be immediately referred to, lie chiefly in the hollows and valleys, it is plain that these depressions must be at least as old as the glacial period. Indeed, it requires little more than a cursory examination of the surface to assure us that

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the general contour of the ground, its hills and valleys, its declivities and watersheds, must have been on the whole the same during that period as they are at present. The valleys have here and there been widened and deepened, and some new ravines may have been eaten out of the rock; but such changes have been comparatively slight. The framework of the county, so far as we can see, remains the same now as it was when the older members of the Drift were deposited. But as the most ancient of these deposits resulted from an enormous abrasion of the surface of the land, it is quite possible that not a few of the minor valleys of this district were produced at that time. The abrasion, however, was so prolonged and stupendous, that most of the distinctive features of the land-surface appear to have been effaced. The soil, the vegetation, the lakes, the rivers, have been swept away, and a mass of variously formed detritus has been left over their former site.* Nevertheless, there are one or two localities in the district where we seem to get a glimpse of some features of the land-surface during, if not prior to, the earlier part of the Drift period. Along the northern part of the coast-line between Cockburnspath and St. Abb's Head, there are some deep and narrow ravines descending from the high grounds to the sea. With the exception of some remarkable defiles at St. Helen's Church, they are all occupied by tiny rivulets: and their sinuous course, with the continuity of the strata over which they run, proves that they are not mere rents or gaping fissures, but that they have been gradually hollowed out by the power of running water. Now, at the bottom of some of these ravines, in little crannies which have been protected from the streams and runnels that descend the steep banks on either side, there lie here and there little nests of boulder-clay. These are not mere patches which have been precipitated from the cliffs overhead by landslips, for we can see sometimes the cross section where an old ravine is choked up with boulder-clay, and the present rivulet is slowly clearing it out again. Examples may be seen at the Menzie Cleuch, near the Redheugh Shore, in the deep defile of the Dulaw Dean, and in several other water-courses along this coast-line. These channels are thus evidently older than the boulder-clay which lies in them, and as they are manifestly the work of streams, they present us with traces of the water-flow of the country during some part of the glacial period, if not prior to that period altogether. There are no localities which promise better to reward a diligent examination of the boulder-clay, than these ancient water-courses. There, if anywhere, we may expect to meet with traces of the plants and animals which inhabited Scotland during the earlier part of the glacial period.†

But besides the ravines just referred to, which are plainly the work of rivulets, there are certain other narrow glens, defiles, or channels (for they vary not a little in size), in which there are either no streams or runnels so tiny and local that they cannot be imagined capable of

* I may mention that traces of the old bed of the Whiteadder in glacial times, with its gravels and clays lying under the boulder-clay, are to be seen on the bank of the stream between Priestlaw and Cranshaws. The ancient glacial alluvium of the Dye Water has also been partially preserved under the boulder-clay, a short way above the junction of that stream with the Whiteadder. Both these localities occur in Sheet 33 of the Geological Survey.

† It is a remarkable fact that nearly all the mammalian remains and the vestiges of terrestrial vegetation yet found in the Drift deposits of Scotland have occurred along lines of valley. I have drawn attention to this fact in a paper on the Glacial Drift of Scotland published in the Transactions of the Geological Society of Glasgow. Part II. 1863.

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hollowing out by their own unassisted operations such marked excavations as those in which they now flow. On the south side of St. Helen's Church, for example, there is a deep winding ravine, quite dry, running along the side of the declivity which here descends gently to the edge of the sea-cliff. It is open at both its eastern and western extremity, thus running across the neck of a promontory. With the present configuration of the land, no stream could ever have flowed along this ravine. Other but less-marked examples may be seen along the sea-front of the hills eastward towards St. Abb's Head. Along with these features ought probably to be classed those valleys which go right across the watershed in different parts of this district. Reference has been already made to the valley traversed by the North British Railway as affording a good illustration. Another occurs in one of the tributary valleys to the west. The course of the little rivulet of the Pease Burn, when it ascends to within a few yards of the flat watershed, turns sharply round to the north-west, and follows the line of the ravine known as Edmond's Dean. This is a narrow sinuous defile, excavated out of the hard Silurian rocks. In ascending it, we at last cease to be accompanied by the rivulet; there is a flat meadow for a short distance, but the winding sides of the dell run on as before, until when we again meet with running water, we see that it flows in the opposite direction, or towards the north-west, descending by the farm of Ecclie to the Heriot Water. The water then makes a detour round Ewieside Hill, and eventually reaches the Pease Burn just below the bridge, and only about 500 yards from the sea-shore. In such a case as this, it is conceivable that two streams should have eaten their way backward until the neck of land or *col* separating their water-courses was cut through, and the two united into one ravine traversing the watershed. But over and above the power of running water, and especially in such ravines as that of St. Helen's, where no stream could have come into play, we must have recourse to some other agency. The eroding power of ice, which is so marked in the rounded and mammillated contour of the ground, was in all likelihood concerned in the hollowing out of these ravines, taking advantage, as it would do, of any water-course or channel already existing, deepening, widening, and extending it, and then leaving it to be subsequently modified by the renewed activity of running water.

Dressed Rocks.—In what way soever we may explain the gulleys and ravines just described, it requires little more than a casual survey to assure us that the surface of this district, in common with that of the rest of Scotland, has been ground and shaven down by some agent of enormous magnitude. The vertical strata of Silurian grits and shales have their arches and edges as abruptly shorn off as the fibres and knots of a piece of wood are smoothed down under a carpenter's plane. The hills wear a rounded mammillated look; the valleys, in certain tracts, particularly on the comparatively flat moory ground between the Eye Water and St. Abb's Head, have a persistent trend in one direction, which is from N.W. to S.E., even when they contain no running water by which their outlines might have been modified. When the observer places himself on some eminence commanding a view across the Coldingham Moors, or on one of the craggy knolls in the vicinity of Dulaw, the fact is vividly impressed upon him that the land ice, which has played so important a part in moulding the present configuration of hill and valley in this country, must here have come in immense force and thickness from the north-west, pressing steadily down the hollows, and taking advantage of any inequality in the texture or surface of the rock so as to form new channels for itself along the line of its flow, thus smoothing off

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the knolls and crags, and communicating to the general surface that rounded and flowing outline by which it is still characterized.

Although the surface of the country retains the form which was given to it by the eroding power of the ice of the glacial period, the nature of the rocks over most of the present district is such that the finer striations by which the course of the icy stream was marked have gradually disappeared except where protected by a covering of clay. They are still visible, however, on some parts of the exposed front of the hills overlooking the sea between Cockburnspath and St. Abb's Head. Their direction corresponds with that of the valleys of the same neighbourhood, *i.e.*, from north-west to south-east.* I have not observed them elsewhere in this district.

The superficial deposits of Berwickshire may be grouped as under :—

Storm beaches.
River alluvium, peat and lacustrine marls.
Raised beaches?
Drift Series { Sand and gravel ridges (Kames), and brick-clays.
Boulder-clay or Till, resting on dressed rock-surfaces.

Boulder Clay.—This deposit presents here the features which usually characterize it throughout the rest of the country. It is a stiff, sandy, and gritty clay or earth, well charged with small gravel and stones, more rarely, with large boulders. It bears a close conformity in colour and composition with the rock on which it rests. Throughout the Silurian tracts it is of a dull blueish-grey or pale fawn colour, and consists of comminuted Silurian detritus. Eastward, where it lies on the red sandstone, it shows a bright red tint. It is always thoroughly unstratified, and so far as I have observed, it does not here contain any intercalations of stratified materials. With the exception of the coast-line near Cockburnspath, in no part of this district does any other deposit intervene between the boulder-clay and the underlying rocks. Along the shore, however, where the Pease Burn enters the sea, and also at intervals for some distance towards the north-west, there occurs an irregular band of shingle, frequently bound into a compact mass by carbonate of lime. It rests usually upon the red sandstones of the cliff, sometimes upon a sandy clay with scratched stones, and is covered by a similar clay, also containing striated and polished stones. This intercalation of shingle appears and disappears fitfully along the cliff-line. It contains large round boulders and partings of sand, and is nearly as firm and compact as any of the Old Red conglomerates of the neighbourhood.

The best sections of boulder-clay in the area embraced in the present map are in the ravines near Cockburnspath, and in the Ale Water about a mile above its junction with the Eye. But the deposit may be examined in some part of almost every water-course. Its absence, indeed, from any part of the surface seems chiefly due to the effects of denudation. On many of the hill-sides in the Silurian district we can trace the gradual disappearance of the clay as it ascends the slopes. In the bottom of the valley, it may be found lying in considerable thickness, and exposed along the banks of a stream. Mounting the hill, however, we find that the surface shows an increasing proportion of angular fragments of the ordinary Silurian rocks of the neighbourhood, the more rounded stones of the boulder-clay become correspondingly fewer, until we at last find the solid rock protruding from the surface, and giving rise by its decomposition to the angular detritus of the declivity. Yet even here we can

* Sir James Hall was the first to observe them here. My observations give W. 35 N. as their line of bearing.

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detect, scattered over the surface, occasional rounded and even striated stones, showing that the boulder-clay once stretched over the hills, from which in the course of time it has been washed off. The clayey matrix has been carried down to augment the alluvium of the valleys, and the stones are thickly dispersed through the soil at the base of the hills.

Sand and Gravel Mounds and Ridges. Brick Clays.—Overlying the boulder-clay in different parts of Berwickshire are masses of sand and gravel, which occur sporadically, in patches sometimes of extremely limited extent, and without any clearly definable relation to the form of the ground. They lie sometimes along lines of valley, as in the defile of the Pease Burn, sometimes across a valley, as on the north side of Borthwick Hill, near Dunse, sometimes along the side of a hill or sloping ground, as on the coast near Lamberton Toll, and sometimes in straggling patches that run indiscriminately over hillock and valley, as round the village of Cockburnspath. These deposits are usually well stratified and fine in texture; occasionally they pass into coarse shingle, where the stratification becomes indistinct. Their general outline is that of low mounds and ridges, but in some places they rise up steeply from the boulder-clay surface on which they rest, and then look not unlike artificial embankments or lines of rampart. The best illustration occurs on the north of Borthwick Hill, where a ridge of coarse gravel and sand crosses the road leading from Dunse Castle to Castle Mains and stretches westward for about half a mile. Within a short distance of its western extremity it crosses the valley obliquely, and is cut through by the stream by which the valley is traversed. This is one of the most prominent parts of its course; a huge mound, or *kame*, like an artificial rampart, has been laid down across the valley, and through this the stream has cut a narrow passage for itself. Irregular heaps and hillocks of the same materials are conspicuous between the turnpike-road and the edge of the sea-cliffs at Lamberton Toll. The upper part of the ravine of the Pease Burn shows a vast thickness of coarse shingle, and similar deposits occur in the valley of the Eye Water at Houndwood, and along the high grounds on the west side of the same stream, where it is joined by the Ale Water. No organic remains have yet been detected in these beds.

These masses of sand and gravel appear to a large extent to have resulted from the washing away of the boulder-clay. We might expect therefore that in some parts of the district, the finer argillaceous portions of the boulder-clay ought to occur, filling up hollows of the older deposits, and forming fields of brick-clay. There are almost no brick-works, however, in this part of the country, nor do the streams lay open sections of these finer clays. The only exposures which have occurred in the progress of the Geological Survey are those in the brick and tile works at Linthill on the banks of the Ale Water, and on either side of the Whiteadder at Edrington Castle. At the latter locality a fine reddish clay with a few striated stones scattered through it is worked. No organic remains were observed in it.

Raised Beaches.—As the greater part of the coast-line rises from the sea in a nearly vertical cliff averaging at least 200 feet in height, the lines of raised beach which occur round the Scottish coast at levels of 25 and 40 feet above high-water mark are hardly to be looked for here. The lower terrace, however, is faintly seen in some of the little inlets that vary the outline of these wild shores. At Coldingham Bay, for instance, and in that of Eyemouth, there are tolerably level sandy flats, from which the ground slopes up into the interior, and which may represent the lower raised beach. Nests of shells and sand are occasionally to be seen among the crannies of the cliffs, 100 feet or more above the sea,

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but these have, in all probability, been swept up by storms. Some of the sea-birds, also, carry littoral shells to their perch upon the cliffs.

Along some precipitous parts of the coast-line of Scotland, the ancient level of the sea is marked by a line of caves, at a considerable height above the present high-water mark. But in no part of the long line of cliffs from Cockburnspath to Berwick have I detected any cave which distinctly proves a rise of the land. The only instance of a cave above the present sea-line occurs back from the edge of the cliffs between the old church of Lamberton and the sea. There, along the sloping ground that descends to the summit of the sea-cliff, a cave has been excavated, apparently by the sea, out of the Carboniferous sandstones. It has irregular, well-worn pillars and a steep roof, the floor being about 215 feet above the mean level of the tides. I could not trace any line of erosion along the coast at the same level as that occupied by this cave.

Lacustrine Marls, Peat and River-Alluvium.—Several of the areas now occupied by peat mosses appear to have been lakes at a former period. An interesting illustration of this fact was obtained in October 1818, when the morass called Middlestot's Bog on the Kimmerghame estate, in the parish of Edrom, was drained. Under the peat moss which was seven feet thick lay a bed of shell marl, varying in thickness from four to eight feet. Immediately on the surface of the marl, and lying as a thin partition between it and the peat, was a soft whitish layer of various mosses, among which *Sphagnum latifolium*, *S. capillifolium*, and *Hypnum cuspidatum*, could be readily distinguished. In this dividing stratum, and extending partly into the marl below, the skeleton of a beaver was found. Owing to the crumbling condition of the remains, only the hard bones of the cranium and lower jaw could be removed to Edinburgh, where they were deposited in the College Museum. Dr. Neill, who described these interesting relics to the Wernerian Society, remarked that on comparing the fossil skulls obtained from marl deposits in Scotland, with recent specimens from Hudson's Bay and Canada, although they apparently all belonged to one species, the former bore a much closer resemblance to each other than to any of the four recent skulls with which they were compared. In the fossil specimens, in particular, the nasal bones were observed to be proportionally larger than the same parts in the recent ones. Several other heads of the beaver were found about the same time at the same locality, but in less perfect preservation. There was probably a beaver colony inhabiting the Edrom lake before the water was gradually displaced by the accumulation of peat.*

The progress of agriculture has done much to remove the wide dreary expanses of peat which once covered so large a portion of Berwickshire. In the north-eastern parts of the county, however, there are still many morasses in the cold barren uplands of the Coldingham Moors. Such are the Long Moss, Drone Moss, Dulaw Moss, Old Cambus Moss, Bellstruther Bog, &c. Many of these appear at one time to have been lakes ; but the only lake still surviving is that of Coldingham, near St. Abb's Head.

Alluvial deposits flank the margin of most of the larger streams, and sometimes, as along the course of the Whiteadder, form broad flat meadow lands, which are known as *haughs*. The best specimen in the present district of this well-marked feature of Scottish scenery, lies between the villages of Chirnside and Allanten, where the Whiteadder

* See Neill, Edin. Phil. Journ., i. 177 ; Mem. Wer. Soc., iii. 207 ; also Statistical Account of Berwickshire, 1841, p. 267.

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and Blackadder waters commingle. A wide, long, and flat meadow, traversed by the united streams, is bounded on either side, but more markedly on the south, by steep banks, by which the edge of the alluvial plain is sharply defined. These banks are, for the most part, cut out of the finely stratified Carboniferous shales and marls already described. It is deserving of notice, too, that even the minor streamlets which descend into the Whiteadder have been able to cut for themselves channels of great depth and precipitousness, out of the same set of yielding strata. This is remarkably exhibited by the streams in the neighbourhood of Foulden and Edrington. The rapid alternation of pale fawn-coloured strata, and the great depth to which these beds have been excavated by even small streams, are appearances which often resemble those of the volcanic districts of Central France, where freshwater strata, not unlike in colour and banded stratification to these Carboniferous shales of Berwickshire, have been similarly worn into deep and wide valleys by the simple effects of running water.

Marine alluvium of recent origin is but of trifling extent in this district, owing to the greater part of the coast-line being occupied by a precipitous cliff. Banks of sand and shingle driven up by high tides may be seen in some of the smaller creeks, as in the little cove of Pettico Wick on the west side of St. Abb's Head. Almost the only sandy beach along the whole coast is that of Coldingham Bay ; all the rest of the sea-margin, with such trifling exceptions as Killiedraughts Bay, is either strewed with coarse shingle and boulders worn from the rocks above, or is formed by detached reefs, skerries, and sea-stacks, among which the tides are ever breaking as they roll along these wild iron-bound shores.

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APPENDIX.

LIST OF FOSSILS.

By J. W. SALTER, A.L.S., F.G.S.

The following list comprises only those fossils which have been collected by the Geological Survey. For the sake of greater completeness, some of the fossils which were obtained from places bordering the area represented on the accompanying map are here included, but in each case the locality is given. It may also be mentioned that the organic remains found in the Carboniferous beds indicated on the north-western margin of this map are inserted in this list, although, as mentioned in the foregoing pages, the description of these strata is reserved for the Memoir to accompany Sheet 33 of the Geological Survey of Scotland.

LOWER SILURIAN (Caradoc).

Graptolithus priodon	Siccar Point; Old Cambus West Mains; Ellemford, near Longformacus.
Tracks of *Crustacea*	Ellemford.
„ of *Annelides*	Do.
Nemertites, wide species	Siccar Point.
„ narrow species	Do.

OLD RED SANDSTONE.

Lower.

Linear grass-like plants, not leaves of *Sigillaria*	Ale Water, near Ayton.
Pterygotus Anglicus, Ag.	Anchencraw Burn.

Upper.

Roots	Banks of Whiteadder, near Cockburn Mill.
Cyclopteris	Do. do. (found here by Mr. Stevenson).
Annelide tubes	Cockburn Mill.
Bothriolepis ornata. Ag.	Harelaw quarry, near Chirnside.

CARBONIFEROUS.

Calciferous Sandstones.

Sagenaria Veltheimiana, Gœpp	Banks of Whiteadder, one mile N.W. of Chirnside.
Cyclopteris	Do. do. shore at Burnmouth.
Coniferous leaves (allied to *Salisburia?*)	Hutton Mill, Banks of Whiteadder.
Sphenopteris	Cove, Cockburnspath.
Lepidophyllum	Do.
Cycadites Caledonicus, nov. sp. A cycadeous plant. (For description see below)	Do., at the bottom of the Carboniferous series.
Athyris ambigua	Cove, Cockburnspath.
Modiola	Do.
Pteronites	Do.
Edmondia unioniformis	Do.
Sanguinolites	Do.
Aviculopecten	Do.
Anthracomya. Sp.	Raven's Knowe, Banks of Whiteadder.
Rhizodus Hibberti. Ag.	Hutton Mill, Banks of Whiteadder.
„ *Portlocki*	Raven's Knowe, Banks of Whiteadder.
Fish fragments	Do.

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CARBONIFEROUS LIMESTONE.

Lithostrotion junceum	Limestone No. 4, north from Berwick pier; Steps of Grace, three miles north of Berwick.
„ *irregulare*	Steps of Grace.
„ *Portlocki*	Do.
Cyathophyllum	Do.
Zaphrentis	Limestone No. 4, north from Berwick pier.
Chonetes Hardrensis. Phill.	Fisherman's Cove, Berwick.
Rhynconella pleuroden	Shale under Limestone No. 2, north from Berwick pier.
Productus semireticulatus, var. *concinnus*	Do.
„ „ *giganteus*	Limestone No. 4, north from Berwick pier.
Streptorhyncus crenistria, var. *cylindricum*	Shale under Limestone No. 2, north from Berwick pier.
Lingula squamiformis	Do.
Spirifer bisulcatus	Steps of Grace.
Edmondia unioniformis	Shale under No. 2 Limestone.
Bellerophon decussatus	Fisherman's Cove, and in shale under No. 2 Limestone.

DESCRIPTION OF NEW CYCADEOUS PLANT.

Cycadites Caledonicus, nov. spec.

CYCADITES CALEDONICUS, *n. sp.*

C. Folia modica semipedalia, rhachide incurvo crasso, subtûs valde convexo, suprâ angustato, pinnis crebris approximatis, fere unciam longis, linearibus, angustis (vix ½ lineæ latis) obliquis, ad basin paullulum tortis, contractis.

The specimen here noticed was found in a hard micaceous sandstone at the base of the Carboniferous rocks, or rather at the base of that portion of them which immediately overlies the red and yellow sandstones of Berwickshire. It occurs at Cockburnspath a few miles S.E. of Dunbar, and in beds which contain a large *Sigillaria*, *Lepidrodendron*, fish defences (*Gyracanthus*), and a few Carboniferous shells. They are the very lowest members of the Carboniferous system in Scotland. The sandstone beds in question are of about the age of the building stones of Edinburgh and Leith and lie far below the true mountain limestone; in some places 2,000 and even 3,000 feet, below the actual limestone beds. These details are given in order to show that the rock in question is much older than the ordinary Coal Measures, and therefore that Cycadeæ are very ancient fossils.

The frond measures 4 inches in length, and consists of a rhachis, 1 line thick, and very convex beneath, and narrow above, on the plane, curved upwards towards the plane from which the pinnæ start. These are closely set, not above $\frac{1}{16}$ of an inch apart at their base, which is contracted immediately after the insertion, and somewhat twisted so as to present the blade of the pinnæ obliquely forward. Pinnæ very numerous, narrow linear, gently curved forwards, about $\frac{1}{8}$ of a line broad, nearly three-quarters of an inch long, and slightly concave. The foregoing diagnosis comprehends all that can be made out from the specimen, which in many parts retains the carbonaceous matter of the plant itself. The apices of the pinnæ cannot be seen, being imbedded in the coarse grit.

There is certainly one cycadeous plant if not more, in the true coal, viz., the *Pterophyllum inflexum*, figured by Eichwald on his Lethæa Rossica, from the coal measures of the Altai mountains. But I do not know that any have been described before from strata so low as the base of the Carboniferous system.

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